

CHILKA

THE PRIDE OF OUR WETLAND HERITAGE



.ORISSA ENVIRONMENTAL SOCIETY:

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Cover Photo : Greater Flamingo (migrates to Chilka from Iran)

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CHILKA

THE PRIDE OF OUR WETLAND HERITAGE

(A STATE-OF-ART REPORT)

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ORISSA ENVIRONMENTAL SOCIETY
1988

FOREWARD

Chilka is the pride of our nation as Asia's biggest salt water lake of about five thousand years old. It is a gift of God and we must save it in its purest form. From time immemorial it has inspired philosophers, poets, and naturalists for its varied birds, fish, wildlife, flora and bountiful natural beauty. Chilka is popularly known for its migratory and resident birds.

Escalating human population has demanded for more and more resource utilisation for sustenance. But unfortunately this has led to resource depletion and pollution threatening the very sustenance of mankind itself. It does not mean that we will not go for resource utilisation and development. But it means that we have to link development with conservation. World conservation strategy advocates for development without destruction or sustainable development.

Thousands of people in and around Chilka have for generations lived in perfect harmony with it. Therefore, Chilka must be protected for their survival also. There is no reason why proper development of the lake cannot take place without destroying its essential and most valued qualities and without depriving the people of the area for habitation there and earning their livelihood.

Research should be carried out in this line and to understand the intricate web of the lake's ecology. Nature lovers, academicians, politicians, administrators and the people of all sections of the society in general must seriously work for long term conservation of the lake for the present as well as the future generations.

P. K. Dash
Speaker
Orissa Legislative Assembly
And
President, Orissa Environmental Society

ACKNOWLEDGEMENT

In 1986 while celebrating the 19th World Environment Day at Berhampur, Orissa, the Orissa Environmental Society organised a national conference on 'Natural Heritages of Orissa' with special emphasis on Chilka lagoon. The conference received financial support from the Department of Science & Technology (DST) of Government of India. But due to limited funds and the need of the contributors of papers for more time the proceedings could not be immediately published. The Society seriously felt that the papers related to Chilka be published in a book form in the best interest of the people. The Society is grateful to DST and the authors of the papers. The book is now published out of the own funds of the Society:

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Editorial

Chilika or Chilka on 19° 21' N 19° 54' and 85° 06' E 85° 35' E is the largest water body of Asia at the East coast of peninsular India in Orissa State. This wetland is an estuarine lake or lagoon because of its connection with Bay of Bengal. Hemmed in between the Green hills in the South and the sea in the North-east the lake is dotted with numerous small rocky islands with their reflections on the still water enhancing its pristine beauties exceedingly picturesque. The total watershed area of the lake is approximately 3,000 square kilometers with water spread area ranging between about 1165 (rainy season) to 906 (winter) square kilometers. It provides more than 6,000 hectares of suitable area for aquaculture sharing about 19 percent in the total available brackish water resource of the State.

The lake is the habitat and shelter place for about 160 fish species, 150 bird species, 2 species of Crabs and a variety of other wildlife and plant species. Barheaded geese, Rosy pelican, flamingos, brahiminy duck in large flocks (and not in pairs and parties as usual) and dolphins at the mouth of the estuary are the features of Chilka lake. It provides excellent habitat for the migratory waterfowl belonging to Siberian-Kazakhstan (USSR)-Pakistan-Indian population which arrive here after rains in large numbers. About 65 species of waterfowl were reported to be sighted in the lake area. As one of the unique waterfowl habitat Chilka lake was declared under Ramsar Convention in 1979 in respect of the "Conservation of the wetland of International Importance" which has been approved by the United Nations Stockholm Conference on "Human Environment". The Bird Sanctuary was also established in 1973 under the Orissa Forest Shooting Rules and closed for hunting.

The lake provides unique natural environment and nursery ground for commercial prawns, crabs and fish. The importance of coastal wetlands to the unlimited fish resources of the sea were emphasized in the world conservation strategy prepared by the International Union for Conservation of Nature and Natural Resources (IUCN), United Nations Environment Programme (UNEP) and World Wildlife Fund (WWF).

The scenic beauty of hilly forests, abundance of avifauna enchanting black bucks on the shore and other wildlife, famous Goddess Kalijai temple island of Chilka lake also offer a vast potential for developing it into an important centre of tourist importance. The temple studded golden triangle of Puri-Konark-Bhubaneswar and the Gopalpur-on-sea and other major and minor places of tourist interest added to Chilka increase the tourist potentialities of the State to a great extent.

Apart from the physical, biological and ecological value the lake also has scientific, educational and aesthetic value. It is rare to find such a combination of all the above mentioned Characters in any other area of the world. Therefore, the lake is claimed to be a unique pride to the Indian sub-continent. "We were impressed to see that the Chilka Lake area is surprisingly still preserved in pristine natural condition without any ugly scar of human degradation. This is an important attribute of the natural beauty of this area," observed in the note "Environmental aspects of the location of the Navy's Boys Training

Establishment (BTE) at Chilika prepared by National Committee on Environmental Planning and Co-ordination (NCEPC) in 1973. Fifteen years after this observation, to-day it is feared that the rate at which Chilka is deteriorating, it may face *death* in not too distant future.

The lake is now faced with certain problems that warrant immediate attention. Those are (a) annual siltation through flood waters of the inflowing river systems, (b) progressive shrinkage of water spread area, (c) inflow of fertilisers, toxicides from farm land, and domestic and industrial effluents and wastes, (d) retarded growth of aquatic flora including plank-tons and rapid spread of weeds (potamoge-ton particularly). (e) indiscriminate tree and shrub cutting from the lagoon land mass and catchment areas of river systems above (mangroves are practically wiped out and the lake islands are bare of trees which provide shelter to birds), (f) over-fishing. (g) 'wildlife poaching, and (h) unchecked slaughter of birds with guns, nests and snores, games and sports.

In February 1980 INS Chilka, one of the premier BTE was commissioned at the vast lush green expanses bordering the historic Chilka lake, for sailors of the Indian Navy. The NCEPC set up by the Department of Science & Technology (DST) of Government of India while selecting Chilka as the site for establishment of BTE clearly mentioned to give attention to environmental aspects to satisfy at least that (a) natural beauties of the area is not spoiled (b) the lake is not polluted, and (c) there is least disturbance to birds.

It was apprehended by the committee that Jantia Hills (wildfowl habitat), Kalijai island (waterfowl habitat and breeding ground of cormorant) and Nalbana Island (abode of birds and the third alternative nesting ground for flamingoes, the elusive migratory birds, after Gujrat's Runn of Kutch and Tamil Nadu's Point Calimore) would be badly affected in particular and the whole of the lake in general. The committee, therefore, imposed certain conditions on the Navy and also suggested the State Government to take some steps in this direction. It has to be thoroughly examined now whether these conditions have been scrupulously adhered to or not and what are the impact of the BTE. Similar steps should also be taken in respect of establishment of the Indian Rare Earth at Chatrapur and other major and minor developmental projects that are growing in near vicinity of Chilka lake.

In the meantime many studies and research work are being carried out to study the environmental aspects of the lake. The Orissa Environmental Society (OES) with the support of the DST, Government of India had organised a national level conference in 1986. The conference recommended the following to minimise the damage to Chilka's environment.

1. The correct etiology and geographical terminology of the "Chilka Lake" is Chilka Lagoon". The Naval Training Centre INS, Chilka are requested to effect necessary changes in the terminology on the location of the training centre and the State Government also should take cognigence of the suggested change, in their records.

2. The islands in the South-western sector of the Southern block be declared as "out of bounds" for the fishermen/for the training excercises of the Naval Training Centre, and

the islands be planted with suitable species of plants to provide adequate nest for the feeding/breeding of birds and to ensure attractive viewing points for the tourists.

3. The Muggermukh area of the Chilka lagoon should be dredged by smaller dredges to deepen the confluence point for effective discharge of flood waters and influx of tidal sea water.

4. Work on digging the palur canal should be completed as early as possible to keep Chilka lagoon region alive and more productive. Fishing should be prohibited within palur canal.

5. The turtle-nesting sites around the Chilka lagoon be identified by the Zoological Survey of India and protected by the forest department, to enable turtle specialists and conservationists together scientific informations.

6. Brackish water fish-farming should be taken up in a rational way, as it is one of the most important methodology to give a high return to improve the socio-economic conditions of the fishermen inhabiting several islands and the surroundings. The State Irrigation Department should identify the peripheral areas which should be excluded from aqua-culture programme for avoiding dangers from flood.

7. Possibilities for introduction of grass-carp or any other suitable herbivorous fish species into the Chilka lagoon for biological control of weeds may be studied by the Fisheries Research Institute of the ICAR or any such other relevant institution.

8. Industries causing air, water and noise pollution should be discouraged around Chilka lagoon, as this may cause harm to the flora, fauna and the migratory birds.

9. The road along the sand-dunes from Rushikulya upto Chilka mouth be made motorable and a number of cottages be built there on to enable tourists to view the enchanting sights, both of the lagoon and also of the Bay of Bengal.

10. An integrated working plan for studying the Chilka lagoon should be prepared by the Estuarine Biological Station (ZSI), Berhampur, Orissa with the cooperation of Governmental and non-governmental bodies to collect base-line data with a view to establishing collaboration with the Chilka lagoon monitoring centre under the Department of Environment.

The Department of Science, Technology and Environment of Orissa Government also held a national seminar in 1988 on "Conservation and management of Chilka." In addition to most of the above recommendations the seminar felt the necessity of (i) Watershed management, (2) stabilisation of the mouth and feasibility study of making additional openings and (3) creation of protective zone in periphery of lake with suitable conservation measures. The seminar also suggested certain long term measures, such as (1) establishment of management information system (MIS), (2) preparation of Status Report covering the environmental components, and (3) longterm research.

It is time now that the conscious citizens, government and non-government institutions should make efforts to conserve this fragile ecosystem of Chilka, the pride of our saltwater heritage, for posturity. Institution of one development authority for effective management of Chilka may help a long way in its all round development including the socio-economic condition of its people.

CONTENTS

	Page No.
The Chilka lake is in danger B. N. Sahu	1
Geomorphic analysis of Chilka lake and adjoining area using remotely sensed data D. P. Rao, S. K. Subramanian & R. Sudarshana	9
Minerals and Sediments of Chilika Lagoon D. V. Katre & G. R. Narayan Das	16
Some Preliminary Investigations on the Variation of Meteorological Parameters over Chilka Lagoon during Nov.-Dec. 1985 A. S. N. Murty	31
Rational Utilization of Brackishwater Resources of the Chilka Lagoon for Aquaculture S. K. Mohanty	36
Fishery Development of Chilka Lake P. M. Misra	40
Growth of <i>Penaeus Monodon</i> in pens in Chilika lagoon and its Ecological significance P. Ravichandran, T. Rajyalakshmi and S. M. Pillai	44
Some observations on the occurrence of Mysids in the Chilika Lagoon P. N. Patnaik	54
Mosquito fauna of Chilka lake area, Orissa A. P. Dash, Namita Tripathy and R. K. Hazra	58
Vegetation and Flora of the Chilika lagoon G. Panigrahi	63
A Contribution to the Flora and Vegetation of Chilika Wild Life Sanctuary, Orissa P. C. Panda and S. N. Patnaik	81
Fauna of the Chilika Lagoon—A Status Appraisal Kaza V. Rama Rao & C. A. Nageswara Rao	86
Avifauna of Chilka Lake K. K. Mohapatra and S. A. Hussain	89
Environmental Survey of Chilka N. K. Das & R. C. Samal	96
Bibliography on Chilika Lagoon Kaza V. Rama Rao, S. K. Mohanty & P. V. Rao	104

The Chilka lake is in danger

B. N. Sahu*

Chilka lake is Orissa's biggest natural wealth heritage. It contributes to economic prosperity of more than a lakh of people living around it. It is one of the loveliest tourist spots of Orissa. It abounds with fish and crabs. It is the sanctuary of both indigenous and migratory birds. But the lake suffers from siltation and over exploitation. Productivity of plankton and fish is on a downward trend. Water pollution is a threat to biotic community of the lake. Conservation and pollution control measures are of prime importance for the survival of the heritage. A Chilka Development Authority may be created to coordinate the activities of different disciplines.

Location and area

Chilka is the largest estuarine lake of the Bay of Bengal situated on the east coast of peninsular India. It lies between $19^{\circ} 30' - 19^{\circ} 57' N$ latitude and $85^{\circ} 5' 20'' - 85^{\circ} 29' 20'' E$ longitude. It extends from Bhusandpur of Puri district in the north to Rambha-Malud of Ganjam district in the south.

The lake normally covers an area of 1055 sq. km. but swells to 1165 sq. km. during the rainy season and gradually shrinks to 906 sq. km. during summer. Out of the gross area of 1055 sq. km., 223 sq. km. is covered by hillocks that lie scattered along the shoreline of north-south side of land mass. The distance between the northern and southern limit of the lake is about 72 km. The southern part of the lake lying in Ganjam district is dented and covers a distance of 5 km. land mass from east to west. (Directorate of Fisheries, 1970)

Natural sectors

The bedrock of the lake is uneven. On the basis of the depth of the bottom of the lake, the entire area can be divided into (1) north, (2) central, (3) south and (4) outer channel sections. Depth of the lake varies from 1.73 to 3.7 meters during the rainy season and 0.93 to 2.6 meters during summer months. The central sector comprising the *Kalijai ganda* is the deepest part of the lake. The mouth of lake *Mugger mukh*—that connects with the Bay of Bengal lies to the north-east of Satpara of Central sector. (Fig 1)

Cycle of changes in ecosystem

River Daya, Nuna, Ratnachira, Bhargavi and Kania of Puri district discharge their flood waters to the north-east sector while Malaguni, Dhanua and Salja from Ranpur-

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Banpur blocks of Puri district along with ten water channels (*Jora*) from Khalikote block of Ganjam district pour their waters into the central sector of the lake. About 3,75,000 cu. sec. of flood waters push out the same volume of saline waters of the lake through Magarmatha mouth to the Bay of Bengal. The lake turns into a sweet water ecosystem from July to December. The lake, therefore, has a sweet-saline environment in a year.

Table 1— Physical, chemical and nutrient characteristics of Chilka lake

Properties	Components	Value/amount
Salinity	pH	6.8—9.7
	Salinity	2.6—35.7 ppt
Physico-Chemical properties of water	Total alkalinity	25.8—157.0 ppm
	Temperature	17.5—32°.0C
	Transparency	69 —116 Cm (Sechl disc method)
	Turbidity	0.08—1.61 mts
	Biomass	
	(a) Bottom of the lake	1.169—1.61 mts
Nutrients	(b) Tidal range at the mouth	0.75—1.57 mts
	Plankton	0.15 cc/litre of water
	Dissolved oxygen	2.6—15.6 per cent
	Nitrate	Trace—0.19 ppm
	Phosphate	Trace—0.80 ppm
	Silicate	0.1—0.60 ppm
	Iron	Trace—0.52 ppm

(Source— Orissa Maritime and Chilka Area Development Corporation, Bhubaneswar)

South-wind begins to blow from January by which time supply of flood waters is being cut off. Saline waters from the Bay of Bengal rush into the lake through Mugger Mukh mouth during high tides. The lake assumes a saline water ecosystem from January to the end of June.

The cycle of sweet-saline change provides favourable environments for the growth of the zoo-plankton and fishes of fresh water for six months and of saline water for the remaining part of the year. The transition period is a critical one. Those zoo-planktons which tolerate both sweet and saline environment remain unaffected by such natural changes. The rest of them along with weeds die creating foul smell and polluting the environment for sometime.

Nutrition of the lake

The lake is eutrophic. Productivity of such category of lake is influenced by (1) nature of the shore, (2) transparency and turbidity of water, (3) temperature, (4) catchment area of water supply and (5) amount, rate and circulation of nutrient. Physical, chemical and nutrient characteristics of the lake water has been presented in Table 1.

Importance of the lake

The lake is important—(1) for its fish and crab population, (2) as sanctuary for local and migratory birds, (3) for changing scenery of its blue water with season and (4) as tourist and recreation centre.

Fish wealth :

The lake is the play ground of 158 types of fish and prawn. Out of this 27 are of sweet water types and 13¹ are of salt water types. Besides Ichthys fauna, Elasmobranchii and Teleostomi have been collected. *Crab-Scylla serrata* and *Nepturus pelageous* are the predominant types of crabs. *Scylla serrata* inhabits the southern sector of the lake as it cannot tolerate sweet water environment. *Nepturus pelageous* inhabit Rambha, Khalikote and Central sectors comprising Balugaon. Very few crabs are found in the northern sector (Seymour and Annandale 1922).

About 60-120 metric tonnes of crabs are caught annually.

Mycids :

Mycids are caught from Kaluparaghat to Barkul where moderate salinity (9.88-12.96%) prevail throughout the year. They are less in Rambha section of the lake. They are also available in considerable quantity in the outer channel and Satpara area. (Tottersal 1915)

Fish economy :

There are 122 villages inside and around Chilka lake. About 60 thousand fishermen that live in these villages depend on Chilka for their livelihood. Seven thousand fishermen are actively engaged in fishing and about fourteen thousand of them are associated with fish trade. 2325 boats, 21,000 or more nets and 1,51,000 bamboo traps are engaged in catching fish.

About 6,000 tonnes of fish are caught annually of which 27.5 per cent are prawns, 17.5 per cent are mullets and 55 per cent are other types.

Winter resort of migratory birds :

The lake is a heaven for indigenous and migratory birds. Food and nesting enterprise near the shore, peripheral woods and Nalabana and other islands like Chadheihaga and

Kalijai have made the lake an attractive habitat for birds which come every winter from Siberia, Tibet and Himalayan region. About 132 species of birds reach their optimum number every winter.

Various birds require various types of niches (Donald *et al.* 1979). These are available in the 1150 sq. km. area of the lake. *Anseriforme* birds like ducks and geese require water of varying depths for their living. *Charadriidae* birds like plovers, sandpipers require very shallow water for their movement. Darter, Cormorant and Grebes require water of particular depth for their underwater hunt and fish of particular dimensions for their food. Large bulk of fish population and shallow to deep water as habitat are the need of Pelicans. The Raptors prey on the coots and ducks and even snatch fishes and sit merrily on the small islands for eating their catch. The gulls and terns dive on to fishermen's net while being drawn out of water. These pattern of habitat, availability of food and shelter make the migratory birds prefer Chilka to Keoladeo Ghana sanctuary of Bharatpur, Rajasthan.

Tourist paradise :

Picturesque islands like 'Honeymoon island', 'Bird island', 'Breakfast island' and 'Kalijai', the sight of migratory and resident water birds on Nalabana island, cruise on the blue water of the lake by country boats and a quiet ride in motor launches have made Chilka a tourist's paradise.

Limnological features

Aquatic weeds play a significant role in the sound health and sickness of the lake. Some weeds serve as food for fish (Turner, 1977). *Potamogeton pectinatus*, *Najas faviolata*, *Scirpus articulatus* and *Halophylla ovalis* are the major species. The first three species are confined to eutropic northern sector and the last are to Nalaban, in central sector. Details of vegetation area (Patnaik, 1980) and vegetation free area have been given in Table 2 (and illustrated in Fig. 2., page 14)

Chilka in danger—Environmental change

Shifting of the mouth and sand casting :

The lake is connected with the Bay of Bengal by the outer channel. The outer channel runs northward parallel to the lake and the Bay of Bengal. The channel length was 24 km. away in 1965. The Mugger Muhan has since shifted south-ward in 1972 due to devastating cyclone and has now two openings off Arakakuda and Nala Banta. The old Harchandi mouth, the northern extremity of the outer channel has been closed. The elevated level of Mugger Mukh is only 30 cm deep in summer. The tidal ingress has now feeble impact on the lake due to size of the channel mouth. Linkage of Palur Bay with Rushikulya estuary through Palur canal has been cut off.

Silting of the lake :

The river systems that feed the lake with flood water during the rainy season carry an enormous load of 13 million tonnes of silt a year render the lake shallow, turbid and a

Table 2—Limnological feature of Chilka lake

Class	Sector	Features	Characteristics	Area covered (Sq. Km.)
I. Vegetation area	Northern	Eutrophication region	A- <i>Potamogeton pectinatus</i> Dense growing 3.87 kg/m ² Negligible influence of tides	124.73
			B- <i>Scirpus articulatus</i> , <i>Najas flaviolata</i> distributed in north-western section	54.47
			Total	179.20
II. Vegetation free area	i) Northern	Turbid water mouth of rivers	Shallow less than 1 m. deep Not influenced by tide	59.74
	ii) Outer Channel Brahmagiri	Saline	Influenced by tide	108.72
	iii) Central or Basin region	Water blue and tranquil	Depth 1.5m.—3.0m., Nalabana and Kalijai islands contain it.	224.63
	iv) Southern or Rambha	Saline	Naval Cadet Training establishment	333.52
	Total	728.61		
Total summer area of the lake				905.81

substrate characterised by loose mud. As the channel mouth of the lake to the sea has become shallow and elevated, the egress of water along eastern bank of Mugger Mukh by northerly wind during October to February is low, as a result the silt load is not pushed out with the sea. The north-western half of northern sector is fast getting marshy at accelerated rate.

Change in overall salinity :

The overall salinity average for the whole lake has dropped from 22.31% in 1957-58 to 13.20% in 1960-61 before stabilisation. The salinity varies from 5 to 10 ppt. seasonally and the northern sector approaches zero salinity in monsoon. Rambha water maintains higher salinity (9-19 ppt.) but it needs to be raised to 15 ppt. minimal level.

Aquatic weed infestation :

The northern sector production—eutrophication region—covering an area of 179.20 sq. km. during summer months is getting badly infested with weeds. Potamogeton species constitutes 78% of weed population. Though some species of this weed are feeds for fishes, other species are causing nuisance. They are hampering water sports and fishing activities. *Najas faveolata* constitute about 14%. These weeds along with Potamogeton species are adding dead organic matter, forming peats and lessening depth of the lake. These dead weeds thrown on the shores by south wind and waves cause environmental pollution.

Fish population on downward trend :

Annual fish output of the lake on an average amounts to 6,500 tonnes. The output is showing a downward trend since 1970 onwards. Percentage composition of commercially important prawns, large mullets, *Bhekti* and *Kontia* are showing downward trend while *Kundal*, *Balargi* and *Jagili* are on the rise.

Influence of refugee fishermen, intensified fishing in the in-shore and off-shore waters, use of nylon nets, catching of fingerlings and over exploitation of prawns in the near-shore waters are causes of the downward trend.

Socio-economic conflict getting complex :

People living inside and around lake area irrespective of caste and creed depend for their livelihood on fish catching and fish trade. An invidious distinction has arisen dividing the population into fishing and non-fishing community.

Pollution of the lake :

Industries are growing up around the western part of the lake. Waste water of the industries, oil from bilge water of the Naval Cadet training ships and power driven boats are being discharged into the lake.

The lake is being fed with 3,75,000 cusec of water by different river systems during the rainy season. Industries are developing in the catchment areas of these rivers. Residues of chemicals and fertilisers used for intensive agriculture find their way into the lake and the outer channel.

Nalabana covering an area of about 8 sq. km., situated in the central sector of the lake, is the visiting ground of migratory birds from October to March. Illegal exploitation of this area is a threat to the safety of the migratory birds.

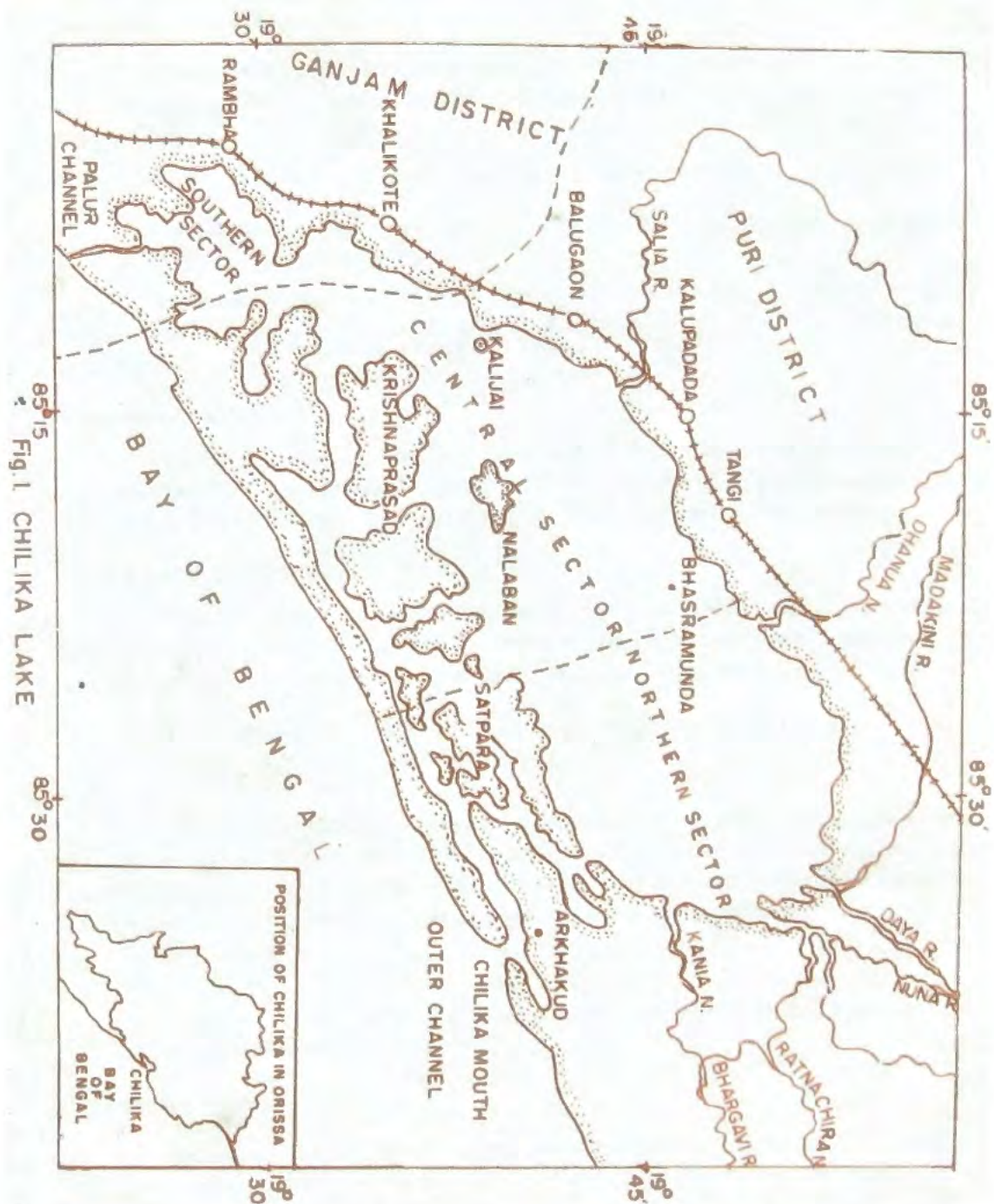


Fig. 1. CHILIKA LAKE

The area around the lake appears to be once covered by trees and forests. But at present cultivated fields and grazing lands extend upto edge of the lake. New plantation of casurina and cashewnut plants are coming up along outer channel. There is acute shortage of fuel wood.

Aquaculture between Arkha-Kuda and Satpara is a threat to dolphine movement. Low lying areas between Nuapara island and Bajrakote area in the southern sector are the play grounds of prawn juveniles. Aquaculture in these areas is a threat to fish production.

Chilka—to be saved and conserved

Justful exploitation, and long-term and short-term management of resources can only save Chilka lake for the posterity.

These measures relate to biological, social and technical aspects. Priorities are prevention of silting, adequate tidal ingress and flushing, weed control, social and sanctuary management.

Prevention of silting

Northern sector of the lake covering 179.20 sq. km area is being silted. This is to be prevented. Soil conservation programme in Daya-Nuna-Bhargavi-Malaguni-Salia basins covering Brahmagiri-Kanas-Tangi-Banpur blocks is to be taken up immediately.

Adequate tidal ingress and flushing

Mugger Mukh spit is to be dredged. The area between outer channel and Bay of Bengal suffers from sand casting. This reduces tidal ingress and flushing of sweet water of rainy season. As a result salinity and brackish environment are disturbed.

Palur Canal in southern sector to be deepened

Weed control

Weeds prevent mud layer erosion by bottom flows under tidal or wind driven and deposition of sand patches. Inter tidal vegetation and juvenile prawns are interrelated (Turner 1977). But excessive weed growth is to be controlled. Chemical control is to be avoided as it may be poisonous to fish. Hand weeding during summer is the safest.

Social

Dependence on fishery has to be reduced. Fishing communities may be motivated to brackish water farming and agrophyte cultivation.

Sanctuary management

Nalabana, the assembly island of birds has been declared as a sanctuary. More watch and ward of the sanctuary is needed. Tourist approach from Satpada may be avoided.

to prevent pollution, scaring of birds and interference with movement of dolphins and migratory fishes from the Bay of Bengal.

Perching ground for birds and fuel supply

Bhasramunda, Chadeihaga, Breakfast island, Kalijai hill are to be planted with suitable kind of trees for perching and nesting of birds, meeting of fuel need and enhancing natural beauty of the lake.

Social forestry is to be started along the western border from Kalupara Ghat to Rambha.

Extension education

People are to be educated of saving Chilka, our heritage.

Since the technical, biological and social management involve different disciplines the Government of Orissa may create a Chilka Development Authority, to coordinate the activities of different disciplines.

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Geomorphic analysis of Chilka lake and adjoining area using remotely sensed data

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Introduction

Chilka is the largest brackish water lake situated in the east coast of India between N 19° 28'—N 19° 54' and E 85° 06' E 85° 35', in the State of Orissa. The lake is connected with Bay of Bengal through an outlet which cuts through linear spit that separates the lake from the ocean. The channel connecting the lake and sea is estuarine in nature and embodies ephemeral sandy/silty islands which have a linear axis. Running parallel to the west of the area, it is bordered by hills and at places rocks of the Eastern Ghat promontories jut out into the lake. The Chilka lake spreads itself out into a pear shaped expanse of water, of which the north-eastern half is wider than the south-western half which tapers off into an irregularly curved point (Fig. 1). The lake receives fresh water from the river Daya, one of the deltaic branches of the river Mahanadi and also from several local streams. The lake has a great influence on the region from geomorphological, climatological and socioeconomic points of view. Monitoring of the dynamic changes in Chilka lake is a challenging and demanding task to understand the impact on its environment. Since the life style of atleast about 80,000 people in 124 villages around Chilka lake depends on limnological system, the task of monitoring the dynamic changes invariably reflects on their socio-economic conditions. Though the monitoring of the features of the lake is being pursued by several scientists, perhaps, this may be the first attempt to approach the above mentioned aspects using remote sensing techniques.

The synoptic view and the periodic repeatability of the satellite data over the lake gives an immense opportunity to find out the cyclic variations in its processes.

Previous work

The lake has been studied vividly in the past during the periods of floods, calmness and productivity. Efforts to study the changes in Chilka lake have also been numerous in this century. Annandale and Kemp published 13 papers in the memoirs of Indian Museum between 1913 and 1924, Ramanadhan et al (1964), Patnaik (1971, 1973), Patnaik and Sarkar (1976) and Asthana (1980) have made pioneering studies on various aspects of Chilka lake limnology. However, the problem of synoptic variations in time and space has remained more or less untouched in the past and perhaps it will be addressed in the coming years.

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Methodology

This paper attempts to describe the morphology of Chilka lake with the help of modern methods in remote sensing. It is intended here to bring out the geological, geomorphological, biological and related aspects of Chilka lake using remote sensing data which are far more time and cost effective than the conventional methods.

The multiband spectral data in the form of images, both in panchromatic and false color composite mode, have been used for delineation of the physical features of the lake by visual interpretation. In addition, the digital data in the form of computer compatible tapes (CCT) of Landsat 4 of path 140 and row 046 in bands 1, 2, 3 & 4 have also been used. The date of pass of the satellite was 29.12.84. The CCT was analysed with the help of the Multispectral Interactive Digital Analysis System (MIDAS) comprising of LS 11 $\frac{1}{2}$ computer with video display unit available at IIRS. The Survey of India toposheet No. 74E on scale 1 : 250,000 was also used for finding out the positional accuracy.

Preliminary field check was made after the initial visual interpretation of the images. Study of computerised classification in delineating various landform units and also the limnological condition in and around the lake were made afterwards. After incorporating all the data, a final map was prepared on 1 : 250,000 scale (Fig. 1 & 2) using Kargl Reflecting Projector.

The results of the computer classification units are presented in Table-1.

Discussion

Within the study area around Chilka lake, a diversity of landforms is exhibited. The major geomorphic units can be classified into (1) denudational, (2) marine/coastal, (3) fluvial and (4) aeolian. Asthana (1980) has identified four units, mostly based on the parent rock distribution in which the landforms are evolved, namely (i) hilly country, (ii) rolling plain, (iii) alluvial country and (iv) coastal sand belt. The boundaries of various units were demarcated by him based on the soil type. However, Sinha (1974) identified five morphological units covering the entire Orissa State. They are (i) coastal plain, (ii) mountaneous country, (iii) rolling uplands, (iv) river valleys and (v) subdued plateaus.

Based on the visual interpretation of landsat imagery the geomorphic analysis has been done and various geomorphic units and forms are identified. From the above study the following geomorphic units and corresponding landforms are described.

Denudational landforms

1. Denudational hills :

This consists mainly of the denudational hills and inselbergs bordering mostly south-west and west-north western part of the Chilka lake. Lithologically, they comprise of

Table-1

AREA OF LIMNOLOGICAL FEATURES IN AND AROUND CHILKA LAKE

Features	Charecteristics	Area in km ²
Scirpus articulatus	Weed. Enhances deposition of silt.	54.47
Potamogeton pectinatus	Dense growing flora. Its cyclic production results in eutrophication and sedimentation.	124.63
Turbid water	Shallow, unvegetated area. Influenced by fresh water drainage and tide.	59.74
Main body water	Tranquil and turbid shallow water. More or less stagnant veg-free.	224.63
Rambha water	Tranquil, deep, more or less stagnant. Veg.-free	333.52
Outer water	Narrow channel influenced by tides.	108.72
Lowlying land (Burried pediment)	Silted and reclaimed land. All around the lake border.	90.17
Drainage area (Palaeo + Active)	Active and Palaeo drainage areas mostly in north-east and west-central. Reclaimable and reclaimed.	305.79
Sand dunes (Aeolian)	Seaward edge of the spit separating lake and sea. Island areas adjacent to spit.	322.63
Agricultural land (Alluvial plain)	Reclaimed and stabilised, paddy growth. Mostly behind bunds separating lake from them.	481.18
Nalabana type land (Marsh land)	Formerly weed zone. Depositional silted and exposed lands.	238.16

SUMMARY

Water area (Vegetation free)	726.61
Vegetation area	179.10
Total lake area	905.71
Lowlying land	90.17
Sand dunes and Bland area	322.63
Nalabana type land	238.16
Drainage area	305.79
Agricultural land area	481.18
Area of Chiika influence	2343.64

Khondalites and gneissic rocks of eastern ghats. The higher elevations are marked by the Khondalites whereas the lower topography is made up of gneissic rocks. Lateritic relief forms the lowest denudational unit. It is observed that the denudational hills with heights of over 625 m are generally dissected. The trend of the crust line extends from northeast to southwest. Fairly thick vegetation covers the entire geomorphic unit.

2. Buried pediplain :

The buried pediplain is distributed in the western part of the lake starting right from the foot upto the western part of the lake boundary. Generally, the pediplain is marked by rolling topography with the erosional bedrock exposed at the foot hills of the higher relief extending over a vast thickness of the alluvium cover and or regolith which need not be uniform all over the buried pediplain area. The pediment gets buried either due to the development of thick weathered profile or due to superficial sediment cover by both fluvial and marine, and is known as buried pediment.

Marine landform unit

The eastern part of the southern half of the lake is covered by coastal plain in the form of small sandbar islands, part of which, where the tidal action is more, get submerged. The drainage pattern in this area is of reticular nature where the drainage channels are inter-connected closely with each other.

In the north eastern part of the Chilka lake, the image interpretation reveals marks of Palaeo Chilka lake boundary about 30 km. from its present position. That means the river Daya was debouching into the Chilka lake about 30 km. north with respect to its present confluence. In the geological past, the area between the palaeo lake boundary and the present lake boundary would have been a mud flat. Subsequently, the deltaic alluvium of Mahanadi river covered this mud flat and presently represents a part of Mahanadi delta system. Intricate type of drainage is seen even now, which normally develops on mud flat areas. The total area of this unit extends approximately 400 sq. km. Some parts of the area belong to reclaimed land.

The eastern most part of the Chilka lake is bordered by a linear sand spit or a barrier spit which separate the lake from the Bay of Bengal. The length of the spit extends for about 60 km. with an average width of about 150 m. Except at two places in the north eastern part where the sea water flushes into the Chilka lake, the barrier spit forms a continuous feature. The shape of the bar is curvilinear, concave towards the sea. From the earlier literature it is evident that the inlets' position and width changes due to the influence of wave action, long shore current in the form of littoral drift and the influence of fresh water discharge and field currents near the lake mouth. However, the landsat image interpretation of two different dates viz. Jan. 1973 and Dec. 1984 does not show any conspicuous changes in this regard, whereas the Jan. 1977 image is marked by the submergence of the coastal plain islands and the rise in water level in the lake is very clear.

As per the Puri district Gazetteer (1977) and IBRD/IDA report (1974), cutting across a channel through the spit would certainly change the present environment of the area, if realised.

Fluvial landform unit

The other geomorphic unit is the deltaic plain extending between the river Daya and the coast form the alluvial plain with very gentle slope towards southwest. Most of the area is under 30 m elevation. This unit supports landuse of crops especially paddy.

Aeolian landform

The coastal sand dunes form a part of this unit which lies all along the northern part with ranging width of 1 to 8 km. The sand dunes are discontinuous with their linear direction paralleling the coast. However, the sand dunes are not like the one we see in the west coast of India where they are well developed.

Based on the image interpretation keys the Chilka lake itself can be divided into three regions (Fig. 2), viz,

	Region No.
1. Production—Eutrophication region	1
2. Turbid—Drainage region	2
3. Deep water region	3

Region-1 :

This is a zone of profuse biological production and is dominated by two species of macrophytes namely *Potamogeton pectinatus* and *Scirpus articulatus*. *Scirpus articulatus*, a weed, is widely distributed in the western and north-western borders of the lake covering an area of 54.47 sq km. However, it is *P. pectinatus*, forming about 78.16% of the macrophytes of the lake (Patnaik 1973), which is responsible for greater production and further eutrophication, covering 124.63 sq km of area. Patnaik (1973) has made an exhaustive study of *P. pectinatus* (locally called as 'Charidal') and has observed that high density of 3.87 kg/sq. m may be observed in some parts of the lake. This essentially means, in a lake in which the tide has negligible influence, occurrence of an annual fresh water discharge of 3,75,000 cusecs and siltation of 13 million metric tons (Samant 1986). *P. pectinatus* expedites further siltation through sediment stability and eutrophication. Hence, *P. pectinatus* is an indispensable factor in the geomorphic variability of Chilka system.

Region-2 :

This region is conspicuous with the drainages of rivers Daya and Bhargavi which are fed by the Koyakhai branch of Mahanadi system (Shetty et al 1965). The waters are

shallow (< 1 m) and vegetation free but are grossly turbid. The turbid waters are so distinct that a front between this zone and the vegetated area may be easily drawn with the help of satellite imagery. While the turbid waters form about 59.75 sq km of the coverage, the drainage area to Chilka lake, involving a small region on the western bank (Fig.2), forms 305.79 sq km.

Region-3 :

An average depth of 1.5 to 3.0 m is found in the region. The waters are tranquil and vegetation free except that the banks often harbour macrophytes of the type, *Halophila ovata*, *Gracilaria lichenoides*, *G. cofervoides*, *Enteromorpha intestinales*, *Cladophora glomerata* and *Chaetomorpha linum*. Most of these plants grow in monsoonal influence, but however, they do not seem to play any role in the geomorphological changes of either lake bed or bank due to their sparse distribution. The waters in this region spread between elevated range lands and the islands are as high as 100 m. In Fig. 2 these waters are called as Rambha waters, the name derived from the biggest village on the bank. That apart, Rambha waters is the greatest single feature of Chilka lake, covering about 333.52 sq km of area.

Computer aided classification

By using the computer compatible tape of this area, the digital analysis have been carried out using Multispectral Interactive Digital Analysis System (MIDAS). The classification of the area into different morphological units was carried out by using the well known parallel piped algorithm by feeding different known area information into the computer. The total area in terms of each limnological unit was also computed and the results are shown in Table-1.

It is seen that the actual lake area, comprising the space enclosed within its pearshaped shoreline, but excluding all exposed land fractions, is 905.71 sq km. This holds true in December which is the optimal state of the lake when it is not influenced by extremities of either monsoonal floods or summer evaporation. However, a total area of about 2343.64 sq km (including the lake) should be considered as the Chilka system as this entire expanse has influences attributable to the lake.

Acknowledgements

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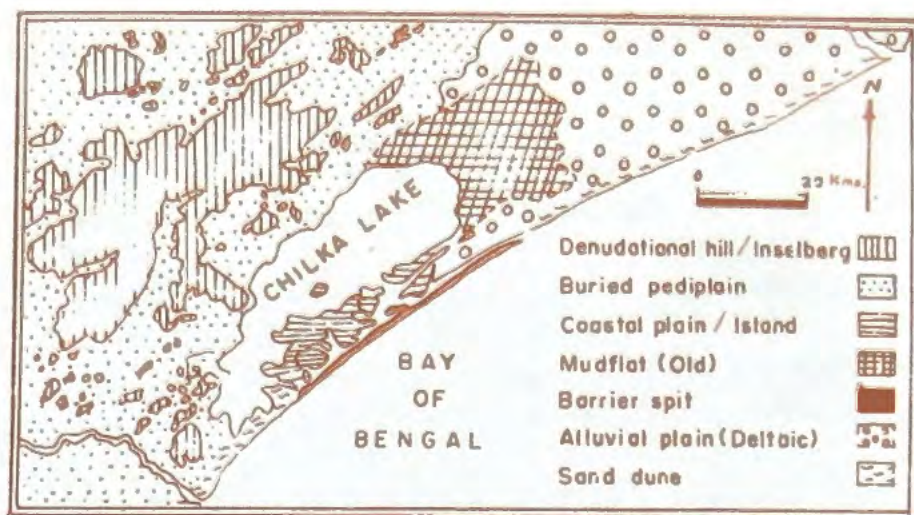


Fig.1. Geomorphological Units Around Chilka Lake

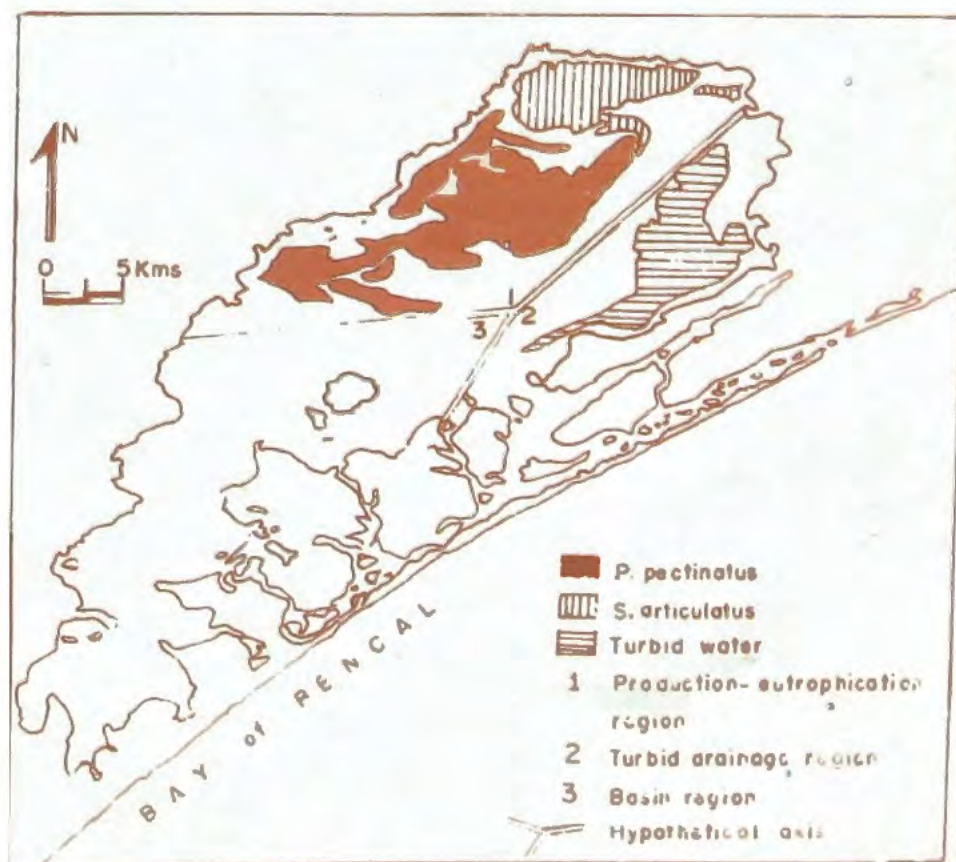


Fig.2. Limnological features of Chilka lake

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Minerals and Sediments of Chilika Lagoon

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The location and extent of the Chilika lagoon, Orissa, along with the physiography and geology in its environs is outlined in brief. An attempt has been made to review and summarise the work carried out as on date by different workers on minerals and sediments of Chilika lagoon and in outlining the physical, chemical and biological processes operative on metal distribution in the lacustrine environment.

The content of the total heavies in Chilika barrier (spit) area was found to be 12.2665%, which is comparatively less than the dunes along the Chilika coastal stretch at Palur Pahar (20.4078%), Bajarkot (26.1935%) and Titipo (15.8065%) with ilmenite, garnet and sillimanite being the predominant minerals with minor heavy accessories like monazite, rutile, zircon, leucoxene and kyanite. Chemical analysis of ilmenite has shown 52% TiO_2 , 34.21% FeO , 4.08% Fe_2O_3 and Cr_2O_3 being 0.06%. Monazite has revealed total REO content to be 60.51% with 9.05% ThO_2 and 0.264% U_3O_8 . A few studies have been attempted in establishing the concentration levels of copper, lead, zinc, nickel, chromium and uranium in surficial sediments and waters of Chilika lagoon. On an average, at depths of 0.5 m, the copper content is 5-14 ppm, lead (72-75 ppm), zinc (38-48 ppm), nickel (135-215 ppm) and chromium (30-40 ppm) with a tendency to increase with depth. The presence of uranium in Chilika waters on average is 1.1 ppb with ranges indicated from 1 to 4 ppb. Preliminary studies have indicated increase of uranium with the increase in salinity of the water.

Introduction

Chilika lagoon deserves special mention because of its peculiar features. Located on the east coast of Peninsular India between latitudes $19^\circ 28' : 19^\circ 54' \text{ N}$ and longitudes $85^\circ 06' : 85^\circ 35' \text{ E}$, in Ganjam and Puri districts of Orissa. It is a unique semi-enclosed pear shaped body of brackish water formed by a wave-built barrier (sand-spit) on a gently sloping shoreline in an elongate basin parallel to the coast. Popular as a birds' paradise and the queen of natural heritage and legacy passed on to humanity and is one of the well known tourist resorts of India. The Howrah-Madras railway and the National Highway No. 5 run close and along its western bank. Rambha, Chilika and Balugaon are the important railheads on the western shore. The village Satpara located on the eastern bank of the Lake can be reached from Puri by a fair weather jeepable road.

Physiography

It is one of the largest brackish water lakes (occupying an average area of 750 sq kms during summer and roughly 1000 sq kms area during the monsoon) periodically

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inundated by fresh water from the two rivers—Daya and Bhargavi—which drain the sediments in the basin. It is connected to the sea (Bay of Bengal) through an outlet at its north-east end in a narrow spit formed by the dominant south-west longshore current. On the coastal side, the barrier bar has a typical curvilinear shape (concave side towards the sea) whereas the landward margin is characterised by irregular shape with tiny cuspidate spits. Here the different energy forces act to supply and distribute sediment from land and sea. The interplay of energy and sediment operates in this shallow body of water which is partly enclosed by a barrier and which has restricted communication with the sea through one or more inlets. The presence of an enclosing barrier distinguishes a lagoon from an estuary. A lagoon is the centre point of two constantly changing and developing energy flows, one from the continent and the other from the open sea. Energy comes physically direct by wave movement, water flow and sediment transport and chemically by import of nutrients and chemicals (pollutants). It comes further more by sun irradiation and evaporation (Krumbein 1981):

Sedimentary processes active in lagoon like erosion, transport and deposition create distinct morphologic and sedimentary features. By recognising these features or by observing the processes directly one can understand the sedimentary processes, formation of heavy mineral assemblages, if any, and the geochemical study of the sediments and waters of the lagoon (Phlegar 1969).

Geology

The chief rocktypes in the environs are khondalites, unclassified granites and gneisses, charnockites, anorthosites, granulites, upper gondwanas, laterite and alluvium.

The khondalites are essentially garnet-sillimanite schists containing graphite in varying quantity as well as some quartz and feldspar. The contact between schists and gneisses appear to be gradual. The commonest form of granite is a coarse grained rock composed chiefly of quartz with feldspar, garnet and usually some biotite. The charnockite shows intrusive relationship towards the khondalites. The acid charnockites are made up of quartz, plagioclase, hypersthene, biotite, magnetite and a certain amount of garnet. By the gradual inclusion of more and more rhombic pyroxene, these acid types give place to dark, lustrous, more or less basic rocks containing plagioclase, quartz, hypersthene with enstatite, and augite, biotite, apatite and occasionally epidote. Garnet, a more or less constant constituent of acid forms, is said to decrease and die out with increasing basicity (Pascoe 1964).

An intrusive anorthosite occurs south-west of Sunakhola. Basic granulites of both hornblende-pyroxene and pyroxene occur as conformable bands of variable dimensions within the charnockites. 2.5% each of biotite and ilmenite are common accessories, the plagioclase range from An_{35} to An_{45} in composition. Gabbroic members comparable in mineralogy with the pyroxene granulites occur within the anorthosites. There are also

intermediate granulites associated with charnockites; however, they have a distinctive calc-alkaline affinity (Fig-1) (Chakraborty & Sen 1983).

Historical perspective

Knowledge of sedimentary processes in lagoon over the past few decades has grown along different lines of enquiry. Early interest centred on morphological features that relates to geologic evolution of the lagoon and barrier island.

1. Geomorphological surveys

Blanford (1872) believed that the Chilika lagoonal lake represents an embayment in the local shoreline and the formation of the spit at the south has caused the origin of this brackish lake, while Pascoe (1964) confirmed the observation by noting 'a hundred miles south-west of the largest Mahanadi estuary and separating the Orissa and Madras coasts in the Chilika lake, a former bay in the sea which the advance of the Mahanadi delta from the north-east, with the help of a sand spit from the Madras side, has hemmed in'.

Ghosh & De (1972) added to the geomorphological observations and considered Chilika lake as a deltaic lake at Ganjam, the lobate arc of the Mahanadi delta upto the shore point at 21°N, is about 200 kms (neglecting the indentations). The projections of the delta is 60 kms. The pronounced lobate projection of the delta clearly indicates the abundance by sediments discharge from a catchment of a large rugged terrain by torrential rains under a tropical climate. The presence of small lakes, in addition to the Chilika, e.g. Sar Lake (c. 4-6 kms) and Samsang Lake (c. 1.5-3 kms) near Puri indicate them as beds of old distributaries (Ahmed 1972).

Compared to its vast area, the lagoonal lake is very shallow with an average depth of 1.5 m. During the summer, the water depth varies from a maximum of 2.4 m in the southern section to maximum of 0.9 m in the northern section. During the monsoon, the lake level rises to 3.7 m above msl. The bathymetric map of the Chilika lagoon clearly indicates a depth in SW section rather than the NE section. Majority of the inflowing rivers to the lagoonal lake are located in the north-east viz., Daya, Bhargavi, Makar and Kusum rivers. Besides these, there are other small streams and nalas in good numbers, most of which supply small quantity of water only during the monsoon. The increased quantum of sediment input in the northeast accounts for the shallowness of the lagoon in that section (Asthana 1976).

2. Estuarine biological surveys

Survey of faunal resources of estuarine areas, brackish water lagoonal lakes and back waters of the eastern coast of India has been recently taken up by the newly established Estuarine Biological Research Station of the Zoological Survey of India at Berhampur. (Gm) These are expected to yield useful data on the fauna of the region. Special emphasis is laid

in the resurvey of the Chilika lagoon as its faunal wealth is considered to have depleted since the last surveys undertaken during the years 1918-23. Annandale and Kemp (1915) have included some details pertaining to the geography, hydrography and vegetation of Chilika while undertaking the first zoological survey of the lagoon. The Central Salt & Marine Chemicals Research Station, CSIR, Berhampur, Orissa is investigating the possibilities of cultivating important medicinal sea-weeds in the lagoon/sea bed floor.

3. Heavy mineral studies

Systematic investigations, though of a reconnaissance type, of the beach placers were first taken up in Chilika area by the Atomic Minerals Division, Department of Atomic Energy, under the guidance of Dr. P. K. Ghosh in the year 1959. Later with the need and demand of the beach mineral industry with particular use of titanium metal in the manufacture of jet-engines, airframes and satellite missiles etc., the survey work was switched over to coastal area of Chatrapur during the period of 1969-73 where the present Orissa Sands Complex (OSCOM) of M/s. Indian Rare Earths Limited came up.

Subba Rao & Virnave (1959) in the course of beach sand investigations of the coastal stretch along Chilika barrier spit running for over 33 kms from a point ESE of Palu upto the Chilika mouth situated east of village Panaspada, noted that the beach zone is rather limited in its area because of the narrow width (50-100 m) while the dunes are very extensive and of varying heights and dimensions from place to place (dune width 500-2000 m). Beyond Palurpahar upto the creek point, the dune zone is characterised by big stretches of low plain ground, where the water level is met within 1.5 m only. The dune zone in this part is confined to a narrow width of 300-600m running continuously along the coast for nearly 25 kms, with the maximum height of dune being 20 m. Beyond the dunes towards the creek side a very thin sandy area runs upto the creek border. The coastal stretch along the Chilika barrier spit has a general trend of N 54° E.

Subba Rao (1964) studied the shifting of the mouth base on wave refraction as an indicative factor viz., (i) the influence of wave action, (ii) the influence of longshore current in the form of littoral drift and (iii) the influence of fresh water discharge and tidal currents near the mouth of the lagoon.

It has been established that above one million tonnes of sand per year moves along the east coast of India in a northerly direction during the south-west monsoon season. The net littoral drift along the Chilika coast being northward, the large quantity of sediment deposition is held responsible for gradual shifting of the lagoonal mouth towards north and for subsequent reduction in the width of the mouth east (Rao 1974).

The average total heavies content of Chilika barrier spit area block was found to be 12.2665%, which is comparatively less than that of Palurpahar block (20.4078%).

TABLE-I
Abundance of Individual Heavy Minerals (% Raw Sand)
Chilika Coastal Stretch

	Palurpahar Dunes	Bajarkot Dunes	Titipo Dunes	Chilika Spit barrier) Beach
Ilmenite	7.7607	10.7320	5.4650	5.0101
Monazite	0.2306	0.2361	0.1150	0.1421
Rutile	0.7856	1.2580	0.7929	0.1900
Zircon	0.8810	1.7658	0.4325	0.1101
Leucoxene	0.8028	0.5290	1.0858	0.1011
Garnet	5.1582	7.6777	5.2076	3.2300
Kyanite	0.0439	0.0124	Traces	Traces
Sillimanite	4.3538	3.6951	2.5070	3.2781
Others	0.3912	6.2874	0.2007	0.2100
Total Heavies	20.4078	26.1935	15.8065	12.2665

(Source : Subbarao J. & Virnave S. N.)

TABLE-I (A)
Chemical Analysis of Ilmenite

Sample	OAP/Ch/2/59	OAP/Ch/3/59
Amperage	(0.3—0.7 amps.)	(0—0.7 amps.)
TiO ₂	52.88%	52.00%
(CbTa ₂ O ₅)	Traces	Traces
FeO	34.49%	34.21%
Fe ₂ O ₃	4.09%	4.08%
Cr ₂ O ₃	0.06%	0.06%

(Source : Subbarao J. *et al* 1959)

TABLE-I (B)
Chemical Analysis of Monazite

Sample	OAP/Ch/1/59 : JSR
Total REO	60.51% (excluding ThO ₂)
ThO ₂	9.05%
U ₃ O ₈	0.264%

Bajarkot block (26.1935%) and Titipo block (15.8065%) with ilmenite, garnet and sillimanite being the predominant minerals along with other minor heavy accessories like monazite, rutile, zircon, leucoxene and kyanite.

Table-I may be referred for the abundance of individual heavy minerals (% raw sand) of the Chilika Coastal Stretch (which includes the dunes of Palurpahar, Bajarkot and Titipo and the beach of Chilika barrier spit). Tables—I(A) and I(B) reflect the chemical analysis of ilmenite and monazite respectively.

TABLE-II
Pattern of Heavy Metal Distribution in Chilika Lagoon

Location	Depth	Sand %	Silt %	Clay %	Carbo-nate %	Organic %	Heavy Metals (in ppm)				
							Cu	Pb	Zn	Ni	Cr
A	1 m	26.0	44.4	29.6	2.1	13.28	62	72	154	180	270
B	1.5 m	50.6	26.9	22.5	2.2	8.02	31	100	90	150	125
C	2 m	31.64	41.16	27.5	2.3	15.4	62	100	154	215	165
D	2 m	35.0	40.4	24.6	2.2	16.50	64	94	118	250	185
E	1 m	46.0	31.2	22.8	2.5	10.72	42	86	96	200	60
F	0.5 m	74.0	7.7	18.3	3.8	4.05	25	94	74	175	35
G	0.5-1 m	73.15	6.35	20.5	3.2	5.18	14	86	100	170	40
H	0.5-1 m	11.20	65.10	23.7	2.8	14.47	45	100	118	270	175
I*	0.5 m	30.50	10.50	60.0	2.3	2.57	8	72	38	135	30
J	1 m	47.00	26.50	26.50	2.4	11.27	38	94	112	180	40
K	0.5 m	15.75	55.75	28.5	1.6	16.54	50	122	144	215	175
L	0.5 m	70.90	16.80	12.3	1.8	10.68	5	75	48	200	35
Mean Values						10.7	37.16	91.25	103.82	195.0	187.9
Standard Deviation						4.82	20.91	14.32	37.0	30.84	74.84

(Source : Asthana V. 1976)

4. Geochemical investigations

Geochemical studies of lagoonal sediments and water are very rare in India. Till date a few studies have been attempted in establishing the concentration levels of copper, lead, zinc, nickel, chromium and uranium in the surficial sediments and waters of Chilika lagoon and in studying their behaviour with some select parameters like CO₃, organic matter and clay fractions. A knowledge of the processes by which a metal is mobilised,

transported, precipitated and possibly remobilised, is of prime concern in order to comprehend possible controls on the metal. The principal mechanisms affecting base metal transport, accumulation and fixation into bottom deposits are thought to involve : scavenging of metals by organic matter; sorption and coprecipitation by hydrous oxides; sorption by clay minerals; chemical processes involving hydrolytic reactions; and variations in the gross physico-chemical nature of the sediments. The range of possible physicochemical-limnological conditions within the lacustrine environment emphasise the complexity of this regime. Variations in these conditions can effect the nature of metal response in lake bottom materials, with respect to mineralisation, in different geographic-climatic and geological environments.

TABLE III

Heavy Metal Concentration in the Sediment core from Site 'A' of Chilika Lagoon*

Depth Intervals (cms)	Cu	Pb	Zn	Cr	Ni
			(in ppm)		
0-10	62	72	154	230	180
10-20	42	100	144	240	150
20-30	45	94	138	135	240
30-40	42	100	100	115	240
40-50	38	86	129	176	275
50-60	42	91	134	230	180
60-70	38	94	134	150	215
70-80	42	94	134	200	240
80-90	45	92	122	175	210
Mean value of sediments below 50 cms depth	41.75	92.75	131.0	188.75	211.25

*One full length core of 90 cms from SW corner of Chilika Lagoon at Site 'A' near Rambha.
(Source : Asthana V. 1976)

Asthana (1976) in the course of his limnological studies of Chilika lagoon, has documented the size grading of sediments from 0.5 to 2m depths of the lagoon and has also indicated a pattern of heavy metal distribution in these lagoon sediments and water.

Table-II shows the pattern of heavy metal distribution and Table III shows the heavy metal concentration in sediment core from site 'A' of Chilika lagoon. It is seen from Table-II that an average at a depth upto 0.5m, the Cu content is 5-14 ppm; Pb : 72-75ppm; Zn : 38-48ppm; Ni : 135-215ppm and Cr : 30-40ppm, while at depths of 2m there is tendency to increase as Cu : 22-64ppm; Pb : 94-100ppm; Zn : 118-154ppm; Ni : 215-250ppm and Cr : 130-440ppm. One full length core of 90cms from SW corner of Chilika lagoon at site 'A' near Rambha shows the mean values of sediments below 50cms depth as under : Cu : 41.75ppm; Pb : 92.00ppm; Zn : 131ppm; Cr : 188.75ppm and Ni : 211.25 ppm.

TABLE IV
Average Values of Heavy Metal Concentration in different
Environments (in ppm)

Heavy Metal	Earth's Crust (Fairbridge 1968)	Chilika Lagoon at Site 'A'	Chilika Lagoon Surface
Cu	70	41.75	37.16
Pb	16	92.75	91.25
Zn	40	131.00	103.82
Cr	200	188.75	107.90
Ni	100	211.25	195.00

(Source : Asthana V. 1976)

Table-V gives a fair idea of the average values of heavy metal concentration in different environments i.e., the earth's crust, Chilika lagoon at site 'A' and Chilika lagoon surface.

TABLE-V
Trace Elements of Chilika Lagoon Waters
(Measured at Surface)

Element	Range	Remarks
Cu	0.02 to 0.04 ppm	Highest at Balugaon & Nalabana
Fe	0.12 to 0.32 ppm	Highest recorded at Kalupara, Balugaon, Nalabana, Mouth of Daya River, Island complex of Sonakuda, Badakuda, Janian at southern part of the lagoon.
Zn	0.025 to 0.19 ppm	Higher near Rambha area and lower in Kalupara

(Source : Asthana V. 1976)

The sampling sites fixed by Asthana (1976) during his limnological studies were in those parts of the lagoonal lake, where the brackish water gets diluted by the incoming fresh waters from two major streams Daya and Bhargavi and scores of other minor seasonal streams and gullies. Though the main body of the lagoon does not fit into the exact definition of an estuary, the chemical constituents of the contained water is estuarine in nature. The salinity proves the fact. Sediments in the lagoon are pooled from both continental and marine sources. Marine and continental sediments are noticed to have a distinct pattern of

TABLE-VI
Chemical Analysis of Chilika Lagoon Water

Location	U ppb	++ Ca ppm	++ Mg ppm	++ Na ppm	+ K ppm	— Cl ppm	= So ₄ ppm	= CO ₃ ppm	HCO ₃	pH	Conductance Milli mhos/ cms
<i>NE Chilika</i>											
Chakripur	1	24	233	1180	59	2415	443	—	146	8.1	9.6
Kalupahar	1	20	53	295	17	604	104	—	159	7.9	1.2
Barikuda	1	40	87	505	31	1094	230	—	122	8.0	3.6
E of Nalabana	1	64	187	1096	60	2340	356	—	122	8.0	9.0
<i>SW Chilika</i>											
Arakuda	2	160	530	3000	175	8320	800	—	90	6.7	23.99
Rambha	4	330	1380	13500	428	19650	3000	—	90	6.94	42.35
Gangadhar	3	170	540	6500	200	6501	800	—	90	7.46	22.58
Average of Chilika Water (32 samples)	1	66	217	1462	64	2621	438	—	135		
Sea Water	—	400	1350	10500	380	19000	—	—	—	—	—

(Source : Biron Mason)

(Analysed : Southern Region Chemical Laboratory, AMD, DAE, Bangalore)

distribution in the lake bottom. It can be seen that the coarse grained sandy marine sediments, entering the lagoon through the channel during the washovers or cyclonic storms have spread along the southwestern and seaward periphery of the lagoon. Detrital matters of continental washout and the product of the shoreline erosion are restricted to the landward fringe, whereas the finer particles of silt and clay sizes are confined to the central part of the lagoon where one can expect maximum settling time because of prevalence of low energy conditions (Allen & Nicholos 1961). Venkatratnam (1965) reported formation of laminated gypsum deposit in Chilika.

- Katre (1984) has reported the presence of uranium in Chilika waters ranging from 1 to 4 ppb. Preliminary studies have indicated that with the increase in salinity, the Uppb values seem to increase. Refer Table-V for trace elements of Chilika lagoon waters (measured at surface) and Table-VI for the chemical analysis of Chilika lagoon waters.

Carbonate content in the lagoon bottom sediments varies from a maximum of 3.8% (at Station-F) to a minimum of 1.6% near the river mouth. The overall pattern of carbonate distribution is very nearly similar to that of salinity. This indicates that much of the carbonate accumulated in the bottom of the sediments is derived from marine sources, apparently from the exoskeletons of marine organisms. Organic matter in the lagoon sediments range from 2.57% to 16.24% with an average of 10.7%. These values are rather high for a coastal lagoon. Phyto-and zoo-plankton productivity is reported to be quite high in the north-eastern region of the lagoon.

Some of the important features of and processes in Chilika lagoon are summarised in Table-VII.

Study approaches

As a guide for future lagoon research, study of sedimentary processes should be organised to focus on: 1. sedimentary deposits. 2. specific processes on mechanisms. 3. the lagoon as sedimentary system and 4. lake sediment geochemistry applied to mineral exploration. For helpful guidelines reference may please be made to the UNESCO Technical Papers in Marine Science (Volumes-31, 32 & 33) brought out by UNESCO, Paris.

The first approach views the bed sediments or deposits as end products of the processes. They are integrated products of many and varied processes deposited by long-term average conditions, or short-term catastrophic conditions. In this approach sediments are characterised by their textural, compositional or structural properties. Study of sedimentary deposits is useful for identifying the important processes at work in different parts of a lagoon and thus good subject for starting a lagoon study.

- The second approach deals with measurements of specific parameters, waves, tides and currents and the corresponding sediment behaviour e.g., velocities required

Table-VII

Features of and Processes in Chilika Lagoon

(Compiled : D. V. Katre)

FEATURE	LOW LATITUDE TROPICAL CHILIKA LAGOON	
Rainfall	1450 mm (June-September monsoon months); seen to increase from SW-NE and varies from 1200-1600 mm.	
Temperature	26.6°C to 27.7°C Maximum : 36.0°C (March-April) 16.0°C (December-Jan.)	
Wind-Speed	Varies from 10 km. p.h. (winter) to 25 km. p.h. (Summer); coastal areas experience more forceful winds.	
Vegetation	Moderate undergrowth & grassy land.	
Radiation	Mean incident solar radiation varies from 90 cal/cm ² per day (Feb.-March) to 150 cal/cm ² per day (July)	
Sunshine	Mean daily duration of sunshine varies from 9 hours (winter) to 4-5 hours (monsoon months).	
Morphology and Development	<i>Lagoon</i>	: Shallow linear elongate arms Coast parallel; Total No. of Rivers : 10 Depth shows a wide variation in different parts : a. Northern part shallow 0.5 to 1 m. b. Deeper part on southern side of Rambha 2 m depth average c. Deepest near Kalijai Island 2.75 to 3 m. d. Channel area varies from 0.01. 2m depending on tidal inflow
	<i>Barrier</i>	: Wide sandy islands with multiple beach ridges Seaward progradation and long-shore migration
	<i>Mainland Margins</i>	: Swamps, marshes & tidal flats locally
	<i>Inlet</i>	: Narrow few ephemeral barrier breaches
	<i>Character</i>	: Salinity : 10.2-11.2% in northern area; 17.8-28.0% in middle area due to influx of seawater 16.0-16.8% (southern) Partly stratified & well mixed Turbidity : 0.08-1.61 m; Colour : muddy yellow to green.

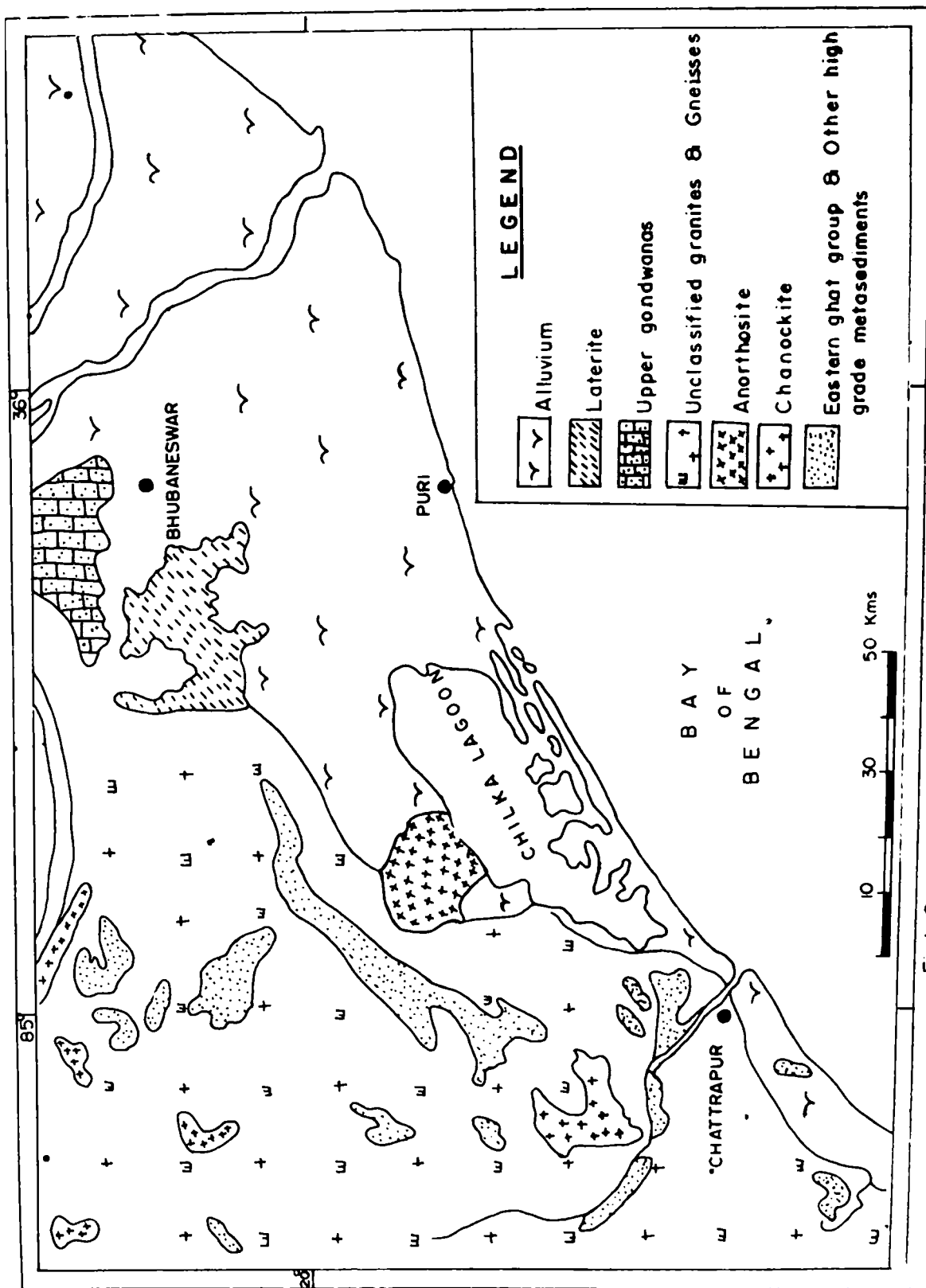


Fig.1. Geological map of Chilka environs , Orissa

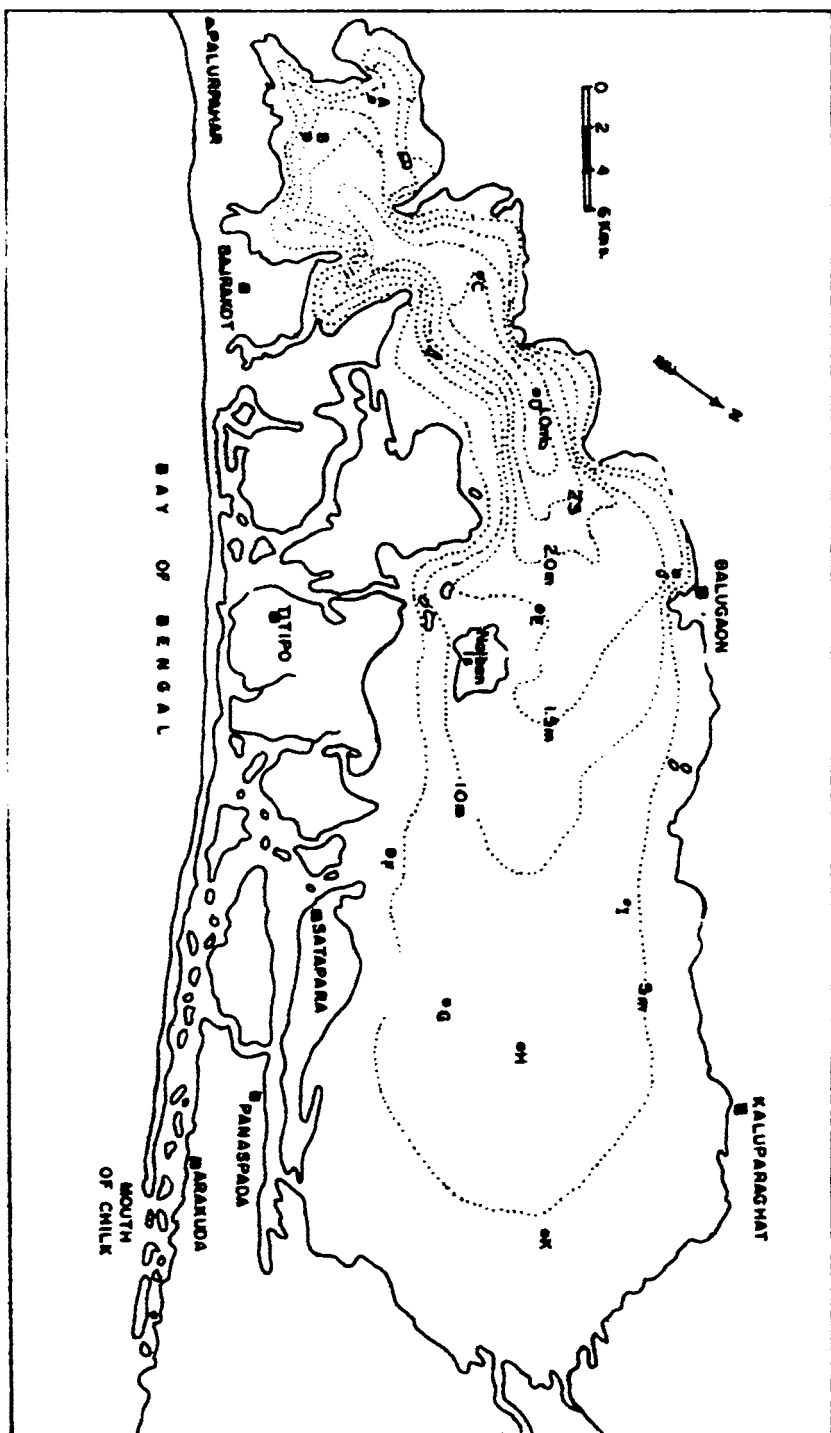


Fig. 2. Bathymetric map (with sampling sites) of Chilik Lagoon, Orissa

	<i>Lagoon-Sea Exchange</i>	: Moderate tidal exchange, high during river floods Dissolved O ₂ : 6.7-7.5 mg/L; Total Alkalinity : 25.8-157 ppm Phosphate : traces to 0.8 ppm Nitrates : traces to 0.19 ppm Silicates : 0.10 to 6.00 ppm Average plankton : 0.15 cc/L
<i>Sediment Sources</i>	<i>Primary</i>	Rivers and streams Volume of annual fresh water discharge : 3,75,000 cus.
	<i>Secondary</i>	Barrier and shore face via inlets and washovers Silt carried into lagoon annually : 13 million MT
<i>Transport Processes</i>	<i>River discharge</i>	River inflow & flooding
	<i>Tide</i>	Low range : 0.3-1.0 m Moderate tides reach up to 5-6 m & areas upto 20 kms inland affected by saline water inundation
	<i>Wave Energy</i>	Very severe storms generated by cyclonic activity (May to November) accompanied by gales, high winds and tidal waves having a destructive effect on the land-use pattern of Chilika area & responsible for gradual shifting of the lagoonal lake mouth towards NE & for subsequent reduction of the mouth width due to settling & accumulation of the transported sands from the sea.
	<i>Unique Processes</i>	
	<i>Seasonality</i>	Rainwash on barrier & breaching. Lagoon flooding, flushing through inlets.
<i>Depositional Processes</i>	Settling of river-borne suspended load entrapment by algae & plant material flocculation & accretion at river deltas	
<i>Bed Sediments</i>	Central lagoon : Organic rich silt & clay or sand mud Marginal Zones : Shelly sands	
<i>Source</i>	: Phlegar F. B. (1969), Subbarao J. (1960), Asthana V. (1976), Rao G. P. (1974), D. V. Katre (1984)	

to initiate particle movement, lag effects of flocculation and process of sediment by organisms. For most lagoon studies, bathymetric chart must be obtained or constructed. When bathymetric surveys are repeated at time intervals of years or decades, the resulting depth changes can indicate rates of sedimentation scour or fill in response to current or waves. Later level variations provide useful basic information on the hydrographic regime of the lagoon. Other physical properties studied over a period of time are pertinent sediment measurement, which include mass concentration of particles, particle size distribution, state of aggregation, organic and inorganic content, sediment composition and heavy mineral assemblages, if any. Such direct observations are essential input for a system study of processes. The principal mechanisms affecting base metal transport, accumulation and fixation into bottom deposits are thought to involve: scavenging of metals by organic matter, sorption and coprecipitation by hydrous oxides, sorption by clay minerals; chemical processes involving hydrolytic reactions, and variations in the gross physicochemical nature of sediments. The range of possible physicochemical-limnological conditions within the lacustrine environment emphasizes the complexity of this regime. Variations in these conditions can affect the nature of metal response in lake bottom materials, with respect to mineralization, in different geographic-climatic and geological environments.

The third study approach may take different directions. It is useful to consider as a sink for sediments from different sources and then draw up a material budget for all contributions.

To study and balance a budget it is necessary to determine the total rate of deposition and the proportions of sediment from different sources. Studies by Biggs (1978) and Bartheberger (1976) show how this approach can be used successively despite limitations of available data. When field data are incomplete assumptions must be made, the dimensions reduced and solutions sought in a mathematical model. Mathematical models have been used with reasonable success for hydrodynamics of lagoon and for sediment in estuaries (Old & Owen 1972) and in nearshore systems (Fox 1978).

Only recently, because of environmental concern over pollution and to a certain extent, because of the application of lake sediment geochemistry to mineral exploration, concentrated attention has been focussed on the study of trace metals in the lacustrine environment (Coker *et al* 1979).

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Some Preliminary Investigations on the Variation of Meteorological Parameters over Chilka Lagoon during Nov.-Dec. 1985

A. S. N. Murty*

Various meteorological parameters like barometric pressure, dry and wet bulb temperatures, air and water surface temperatures, of 45 stations collected in Chilka lagoon during the period from 21st November to 5th December 1985 were analysed. The heat flux parameters of latent and sensible heats, evaporation and momentum flux were computed and presented. It was generally observed that evaporation in the lagoon in this period was low due to low momentum flux. The range of temperatures in general between air and water was also not much excepting at one station (Stn. 16) in Rambha Bay. The latent heat flux dominates the sensible heat loss.

Introduction

Sun is the ultimate source of energy to the earth and its environment. The heat received by the atmosphere and water will be utilised for various purposes and activities, for example, the absorption of heat in the atmosphere causes the motion of air (wind), variation of pressure which in turn causes the development of various weather disturbances. The heat received is utilised for various biological purposes like photosynthesis and productivity and is also responsible for occurrence of different physical processes like development of currents due to variation of salinity and density.

However, it is not so easy to understand how much is the exact amount of heat ultimately received by water. While direct solar radiation from the sun and the indirect radiation from the atmosphere are the main sources of heat income to water, there are three ways by which it (water) loses heat. They are back radiation, sensible heat and latent heat losses. Apart from these main processes, there are some secondary processes, like scattering and reflection of radiation from the water surface and depletion of radiation by the atmosphere. The direct solar radiation can be determined with the help of solar constant which has a value equal to $1.98 \text{ cal/cm}^2/\text{min}$. The parameter determining the reflection and scattering functions is called albedo on the average it is about 30% (Batan 1979). The net income to net loss of heat determines the heat balance of a locality.

In the present study, to make an attempt on the heat balance studies of Chilka lagoon the heat flux parameters of sensible and latent heats and evaporation, over the Chilka waters were studied using the data of 45 stations during the winter (north-east monsoon) period.

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Although several studies on heat balance in other Indian regions are made, only one reference is available for the evaporation studies of Chilka lagoon (Ramanadham *et al*/ 1967). Hence a serious attempt has been made by the author to study this aspect of Chilka lagoon.

Materials and methods

The data on wind speed and direction, air and surface water temperatures, relative humidity, barometric pressure and maximum-minimum temperatures have been collected for 45 stations (Fig. 1) on board in a vessel hired by Estuarine Biological Station (Z.S.I), Berhampur, Orissa during the period 22-11-85, to 5-12-85, using the instruments: anemometer, centigrade thermometer, hygrometer, aneroid barometer and Six's thermometer respectively.

The various formulae used for different computations are as below (Rao and Rao 1985; Murty et al. 1987; Deacon and Webb 1962) :

i) Latent Heat Loss :

$$Q_e = LE = 1.71 \times 10^{-6} \times L (q_o - q_a) u_a$$

where Q_e is 'latent heat loss in ly/day, L is the latent heat of evaporation taken as 585 cal/gm, E is evaporation in langleys, q_o is saturated specific humidity and q_a is the specific humidity of air when temperature is in degrees Celsius, u_a is wind speed in meters per second at the deck level of the vessel which comes to about 3 meters above the water surface.

ii) Sensible Heat Loss :

$$Q_s = P_a \cdot C_d \cdot C_p (T_o - T_a) u_a$$

where Q_s is sensible heat loss in ly/day, P_a is the average air density taken as 1.2×10^{-3} gm/cm³, C_p is the specific heat at constant pressure which is equal to 0.24 cal/gm/degree, C_d is the drag coefficient which is equal to 1.4×10^{-3} for wind speeds less than 14 kts and 2.4×10^{-3} for wind speeds greater than 14 kts. As the wind speeds in this period are less than 14 kts the former value was taken. T_o and T_a are the average surface water and air temperatures in degrees Celsius respectively.

iii) Momentum Flux :

$$T = P_a \cdot C_d \cdot u_a^2$$

where T is the wind stress momentum transfer in dynes/cm² and the rest of the symbols are as above.

iv) Evaporation :

$E = (1.465 - 0.0186 B) (0.44 + 0.118 u_a) (100/r - 1)e$ where E is evaporation in inches/day, B is barometric pressure in inches of mercury, u_a is mean daily wind speed in miles per hour, r is the relative humidity and e is the actual vapour pressure in inches of mercury.

After computation of E in inches were converted to centimeters for the uniform representation in C. G. S. units.

Results and discussion

Barometric pressure

The variation of pressure during the period (22nd Nov. to 5th Dec. 85) was 1008 to 1015 mb. (Fig.2) The lowest pressure was found in the northern sector and the highest pressure near Sananodi in central sector. The lower pressure in the northern sector was due to a low pressure system in Bay of Bengal prevailed during the period of observations. In the absence of low pressure system the general variation of pressure on the surface of the lagoon would be 1012 to 1014 mb.

Temperature

Fig. 3 depicts the variation of different temperatures at air-water interface. Fig. 3 (a) shows the difference of air and water temperatures. It indicates, air temperature was found to be warmer than that of water in most of the time excepting at a few locations and a few days. Under this condition a transfer of heat energy from air to water is expected. The positive values ranged from 9 to 0.1 and negative values from 4 to 0.15. The highest positive value occurred at E_6 (corresponds to station 15 in Fig. 1) on 25th in the right side of Rambha Bay and the lowest negative value occurred at G_{12} (corresponds to Stn. 26 in Fig. 1) on 5th in the left side of the central sector. But the conduction of energy (Q_h) between air and water at these stations was not significant (Fig. 5) because of the lower ranges of temperatures between air and water. Fig. 5 also shows that the maximum conduction (sensible heat) took place at O_{16} and S_{17} on 30-11-85 and 4-12-85 respectively.

Fig. (3b) indicates the dry bulb, wet bulb and water surface temperatures. The highest and lowest values of dry bulb temperatures were 34.5 and 22°C respectively at E_6 (Station 15) and K_{14} (Station 31). Another interesting feature was up to D_7 dry bulb temperature which was higher than the water surface temperature and thereafter both the temperatures almost remained same. That was the reason why evaporation was not very high in Rambha Bay when compared to the northern sector although it was warmer than the rest of the lagoon usually (Fig. 4). While the average water surface temperature was

around 26° C. (Fig. 3) indicates the average dry bulb temperature was 30° C during day time for the whole of the lagoon. Thus the net transfer of heat during day time was expected from air to water and was proportional to 4° C. However, due to the variation of temperature, pressure and wind both at the surface water and air temperatures resulted in the variation of exchange of heat between air and water during the same period (Murty et al. 1987). This was the main reason for low evaporation during this season. The average variation of evaporation over the lagoon was from less than 19×10^{-2} cm/day in Rambha Bay to over 1.5 cm/day in the north western-sector (Fig. 4).

Evaporation

The daily evaporation in the lagoon during the study period which gives the evaporation in the central sector was around 0.65 cm/day (fig.5) which very well agrees with the value of Ramanadhan et al. (1967) who got 0.01 in/hr (0.60 cm/day) in October. Fig. 5 also indicates the variation of sensible heat flux (Q_h) and latent heat flux (Q_e) and momentum flux (T) on every day were also studied for the study period. The latent heat variation was proportional to evaporation and the maximum value was 220 ly/day in the lagoon. The sensible heat had a maximum of 140 ly/day at O₁₆ and S₁₇ stations. On an average the highest momentum flux was around 50 dynes/cm² and lowest was less than 2 dy/cm². Thus the contribution of momentum was not much for evaporation when compared to latent and sensible heats during this periods. It was also evident from (Fig. 5a) that latent heat flux was more than the sensible heat during this period.

Conclusion

Evaporation over Chilka lagoon in November-December 1985 period was less than 0.45 cm/day which was a very small value when compared with the general coastal water evaporations in winter. This may be due to low wind speeds and less significant difference in temperatures between air and water surface.

Acknowledgements

The author wishes to thank Zoological Survey of India for giving the on-board facilities and Dr. K.V. Rama Rao, Superintendent Zoologist, Estuarine Biological Station, Berhampur, Orissa for giving all kinds of encouragement during the period of this study. The author is also thankful to Dr. P.M. Misra, Head of Marine Science Department, Berhampur University for giving the laboratory facilities during the period of this work.

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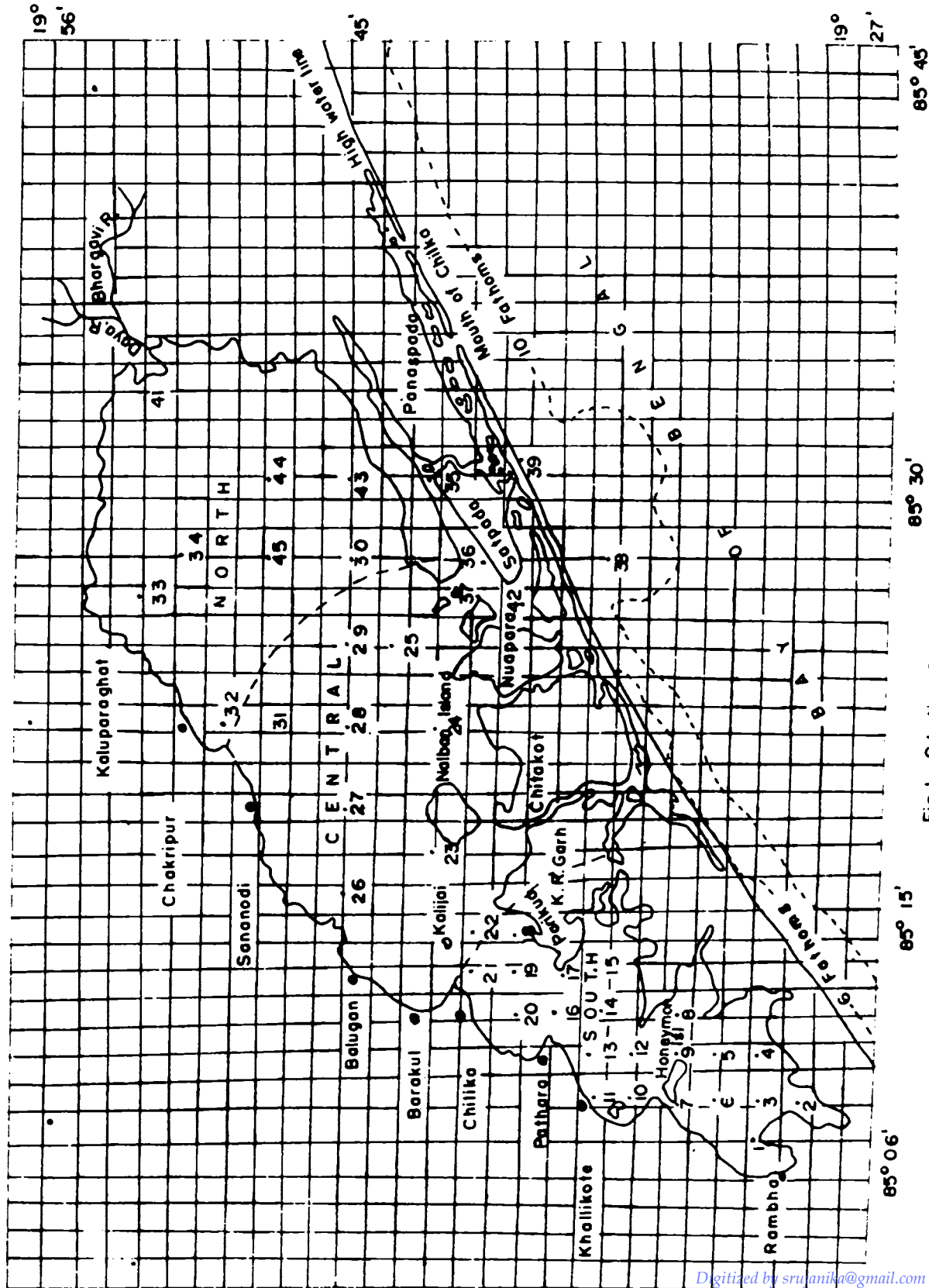


Fig.1. Station Position

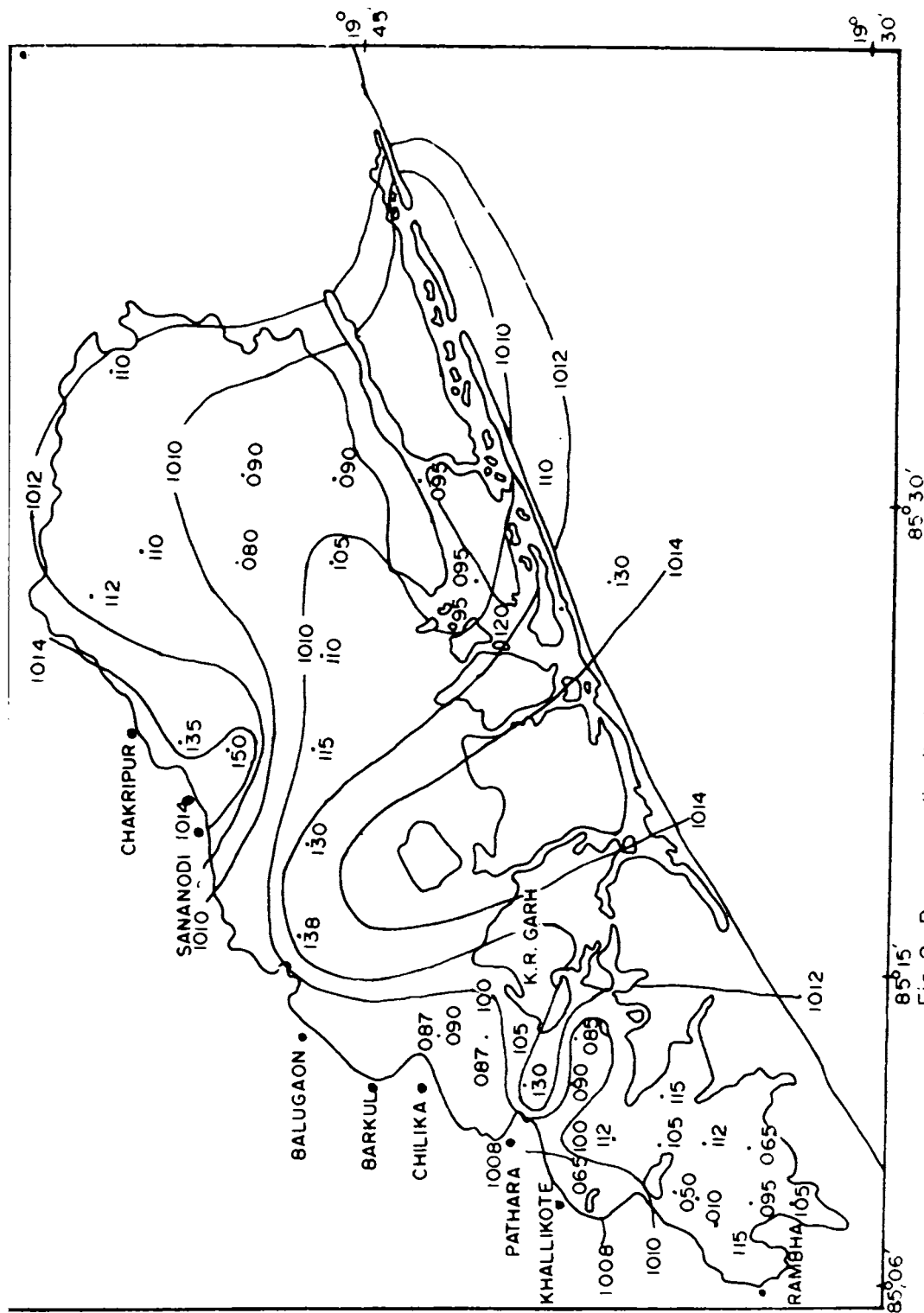


Fig. 2. Pressure distribution (in mb)

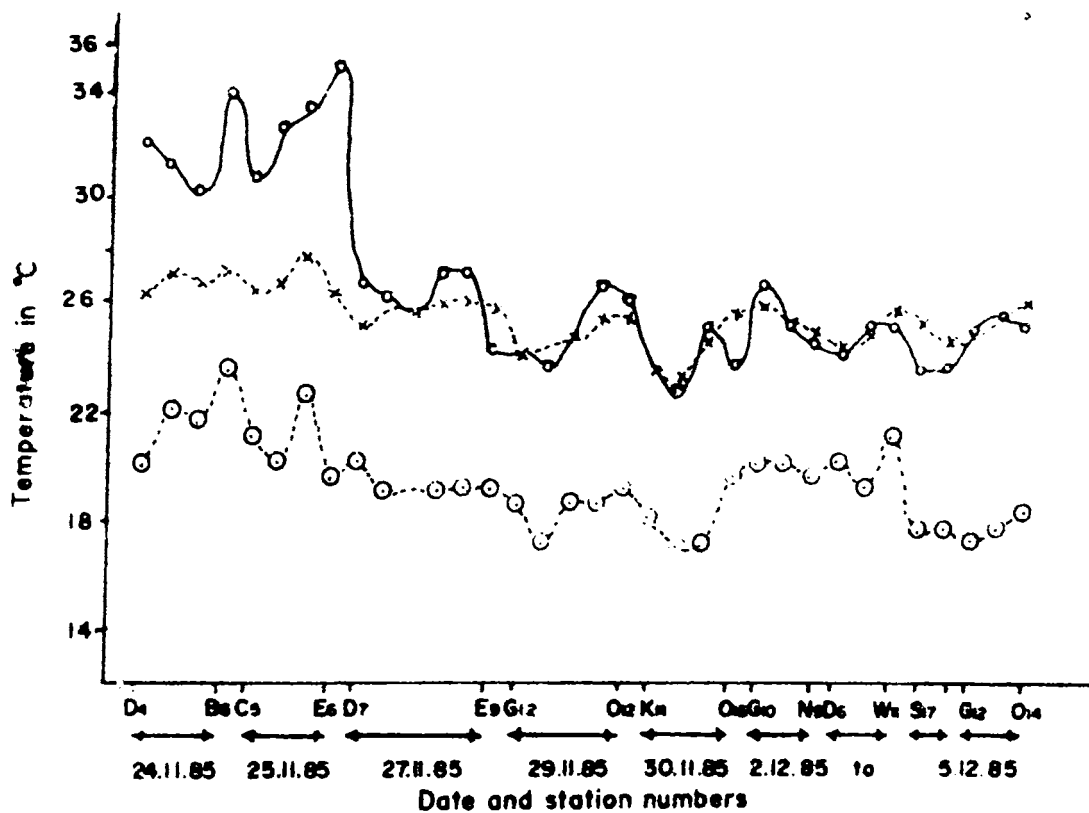
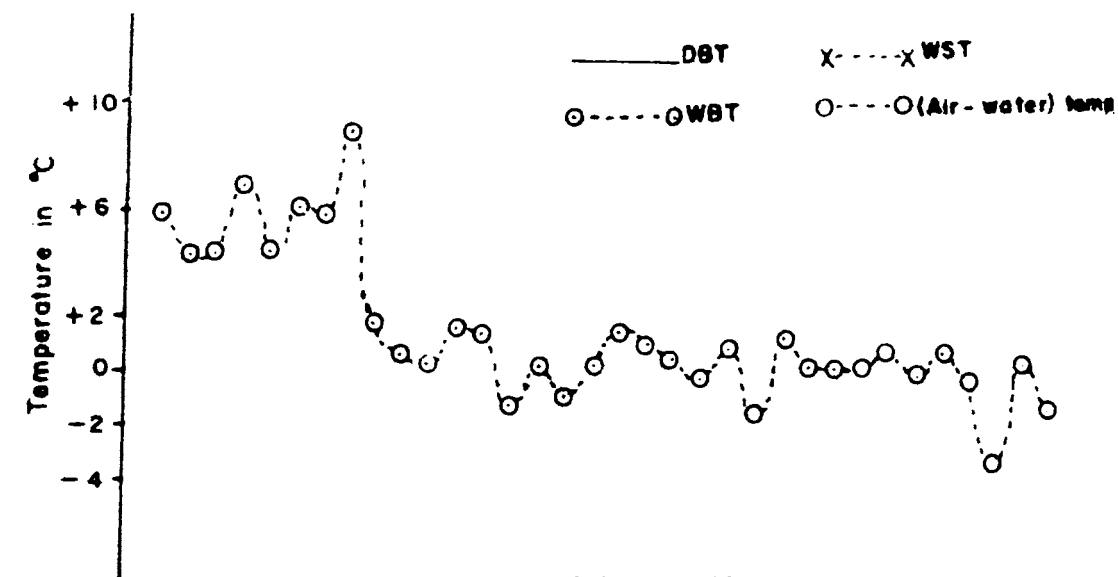


Fig. 3. Variation of different temperatures at-water interface

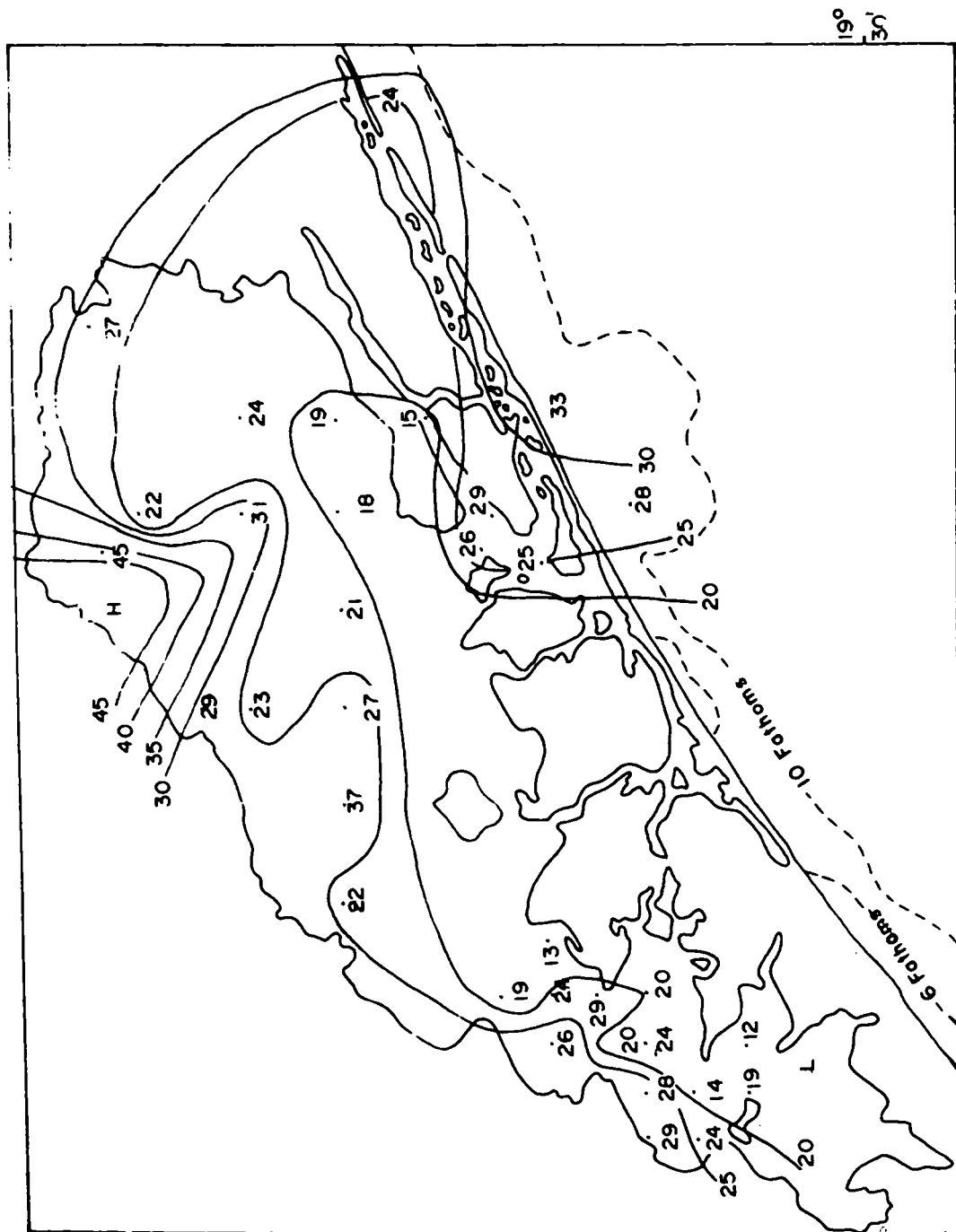


Fig. 4. Evaporation (10^{-2} cm/day)

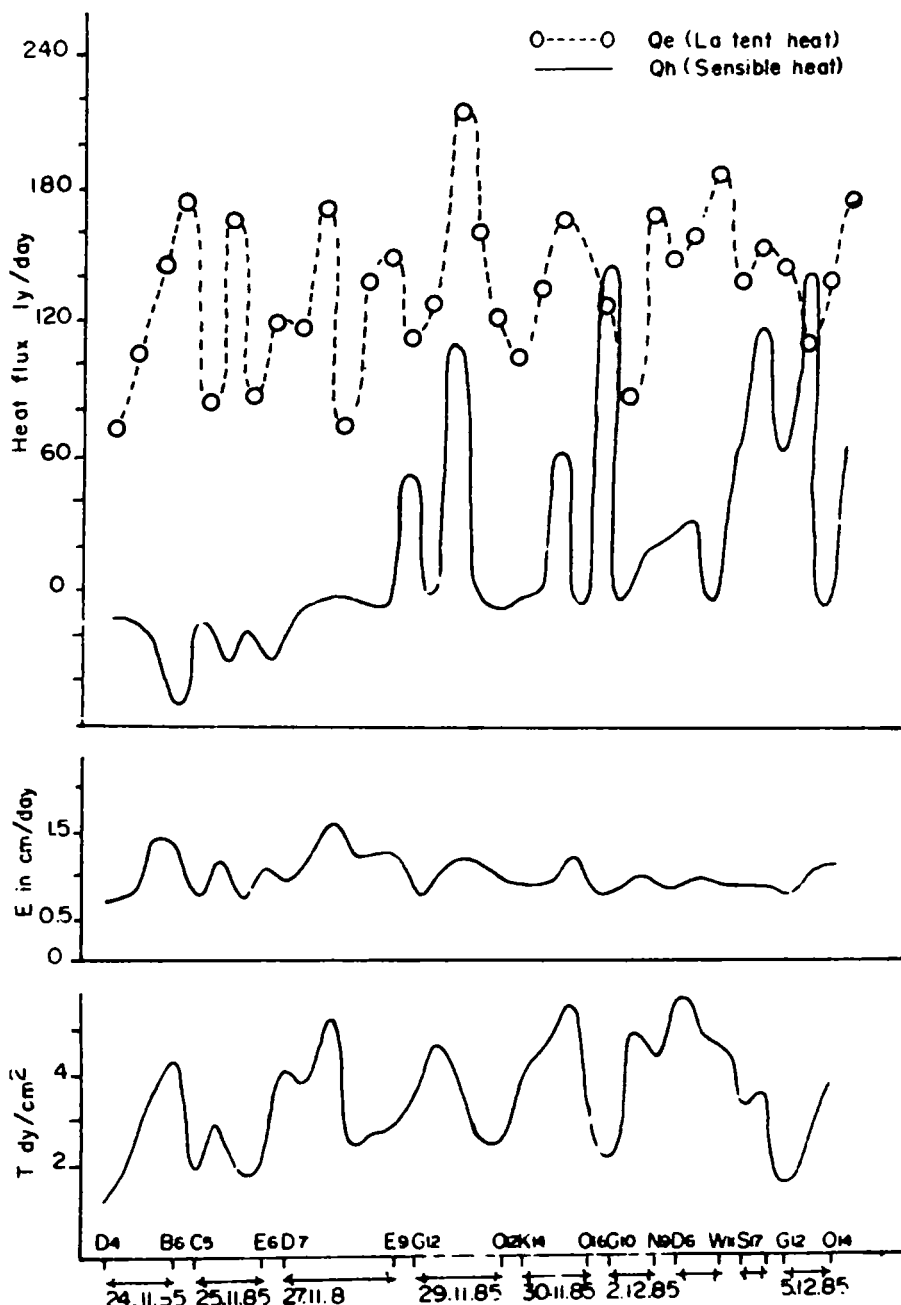


Fig.5. Heat flux parameters and momentum transfer.

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Rational Utilization of Brackishwater Resources of the Chilka Lagoon for Aquaculture.

S. K. Mohanty*

Chilka lagoon on the East Coast provides more than 6000 ha. suitable brackishwater areas for aquaculture sharing 19 per cent in the total available brackishwater resources of the State. Detailed micro-level survey including ecological screening is being undertaken to finally locate the suitable sites for aquaculture projects in and around the Chilka lagoon.

The unique natural environment of the Chilka lagoon provides one of the best nursery grounds for most of the commercial prawns, crabs and fin-fishes. The monsoon flood situation in the lagoon and the traditional capture fisheries on which more than 60,000 fishermen depend for their livelihood have been the subjects of serious considerations while deciding the project sites for aquaculture in the Chilka lagoon. The present estimated brackishwater area of about 6000 ha. for aquaculture may be further reduced through meticulous ecological screening.

Introduction

Wider interest in brackishwater aquaculture in India has been generated in the recent years with a view to increasing prawn and fish production and boost up export earnings. Brackishwater aquaculture, particularly prawn farming in India, is vitally important not only for very high unit value of prawns but also for improving rural economy and, for providing gainful employment to the larger section of rural population.

The State of Orissa is endowed with vast resources of brackishwater areas stretching along 480 km long coast line and the Chilka lagoon. From a latest survey conducted by the department of Fisheries, Orissa, it has been estimated that 36,618 hectares brackishwater resources are presently available in Orissa coast. If these resources are developed rationally and scientifically, it could yield about 8,500 tonnes of prawns annually valued at Rs. 595 millions.

Chilka lagoon alone can provide more than 6000 ha. brackishwater areas for prawn/fish culture (Mohanty 1977) which shares 19 per cent in the total available brackishwater resources in the State. The unique brackishwater environment of the lagoon which provides clayey soil base rich with detritus and benthic food and the most suitable range of soil and water salinity favours very much for development of brackishwater aquaculture,

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particularly prawn farming. The traditional fishing by more than 22,000 active fishermen in the lagoon, conservation of prawn/fish seed resources and the effect of aquaculture development on the natural environment of the lagoon including flood situation need be taken into consideration while planning the aquacultural development in the Chilka area.

Brackishwater environment

The Chilka lagoon which covers a total area of 1388 sq. kms. including 223 sq kms of island areas presents an unique brackishwater environment which is unparallel in the country.

The northern sector and the outer channel sector of the lagoon go almost fresh during monsoon when the two main rivers Daya and Bhargabi, are in floods. On an average, 3,75,000 cusecs of flood waters are annually discharged into the lagoon carrying about 13 million tonnes silt which causes shallowness of the northern sector. The southern sector is comparatively deeper and little influenced by flood discharges. The tidal influence is felt, at the maximum, upto Satpara during winter and summer and the outer channel gets almost filled with sea water and exhibits more or less a marine environment during March-June. The flood waters enrich the nutrient level of the lake and, continuous siltation process in the northern sector forms a thick clayey layer of soil suitable for aquaculture. The annual mean salinity of the lagoon is maintained at a moderate level which provides a comfortable habitat for a large number of fish/prawn species. The aquatic vegetations and benthic fauna are also quite large in variety which provide rich natural food and shelter for fin-fish and shell-fish.

Area available for aquaculture

The maximum water spread area of the lake during monsoon is 1165 sq kms and the minimum water spread area in summer is 906 sq kms. The difference of 259 sq kms area (25,900 ha) is the peripheral zone which remains dry for more than 8—9 months in the year and only submerged during monsoon. In the past, quite a large extent of areas in this seasonal dry zone have been converted for cultivation by constructing embankments. This has reduced the seasonal dry zone areas to a greater extent and increased flood problems.

The macro-level survey conducted by the Department of Fisheries, Orissa in the Chilka area showed that 5,005.79 ha. brackishwater areas are available for aquaculture which was earlier estimated at more than 6000 ha (Mohanty 1977 and 1984). More than 65 per cent of the suitable areas are available in the north-eastern part of the lagoon periphery and the remaining 35 per cent areas as spread over western and south-eastern part of the lagoon. More extensive peripheral flats are available between the mouth of river Daya and Dahikhia creek. Brackishwater areas available in the south-eastern part are most undulated in nature.

Brackishwater seed resources

Seeds of prawns, mullets, pearl-spot, cock-up etc. are available in the Chilka lagoon. The lagoon mouth has been identified as one of the major prawn seed collection centres. Mullet fry are available in considerable quantity near the mouth during November-January. Large quantity of prawn juveniles are caught by the fishermen in trap fishing and killed every year indiscriminately. A recent survey conducted by the Brackishwater Fisheries Development Agency, Puri indicated that about 250 tonnes of juvenile prawns (*P. monodon* and *P. indicus*) which constituted 16.15 per cent of the average annual landings of prawns in the Chilka lagoon are caught and sold by the fishermen which is valued at rupees 25 lakhs. If this much of juvenile prawns are allowed to grow in the natural environment of the lagoon the landings of exportable prawns could be increased to about 2000 tonnes. If the same quantity of prawn juveniles are used as stocking material in the aquaculture projects, about 750 tonnes of exportable prawns at 50 per cent survival could be produced valued at 5.25 crores rupees. This suggests that serious conservation measures should be taken to restrict the indiscriminate killing of juvenile prawns in the Chilka lagoon.

Present status of prawn farming

During the last three years (1983-84 to 1985-86) brackishwater prawn farming in scientific lines has made a head way in the Chilka area where 1150 nos of prawn ponds covering a total area of 281 ha. have been developed. More prawn farming projects have been developed between Kusubenti and Panasapada village in the north-east part of the lagoon followed by Bajrakote area. Presently, only the monoculture of tiger prawn (*Penaeus monodon*) is practiced and the average yield obtained at 250 kg/ha/crop of 3 months. Normally two crops are harvested in a year. The entire production of tiger prawns from these farming projects are exported to foreign markets. The financial institutions have invested more than eleven lakh rupees credit in these projects. So far, 598 families of the poorest of the poor in the Chilka area have been economically rehabilitated through prawn culture under the scheme "Economic Rehabilitation of Rural Poores" sponsored by the State Government. Besides, 165 private farmers have developed their prawn farming projects in the Chilka area through bank credit and 20 IRDP farmers are engaged in prawn farming under a centrally sponsored scheme "Area Development Approach Programme" in the north-east part of the lagoon. More projects are now coming up in north-east and south-east part of the lagoon.

Conservation of natural environment

Chilka lagoon, though offers the best potential resources for development of brackishwater prawn culture in Orissa, its natural unique eco-system requires special reference in respect of conservation measures. The planning for commercial prawn farming in the periphery and inner areas of the lagoon therefore calls for a multi-disciplinary scientific approach so that the natural prawn fishery of the lake, natural habitat of the resident and migratory birds and, above all, the dependence of several thousands of poor

fishermen families on the prawn fishery resources of the lagoon remain unaltered (Mohanty 1984).

If the available seasonal dry zone areas in the periphery will be utilized for aquaculture projects in an unplanned way, the flood cushioning areas of the lagoon, particularly in the northern sector, will be drastically reduced causing high floods. The migratory birds which visit the lagoon every winter in large numbers usually concentrate in several specific areas of the lagoon where more of algal weeds and shallow and calm waters are available. The main food of these birds is not fish so much as minute sludge life and vegetation. Therefore shallow areas in the lagoon which are frequented by these birds need be excluded from the selected areas for aquaculture.

The lagoon mouth where the sea water ebbs out and flows in upto Satpara area in the outer channel dolphins are such a feature of the tidal movements, that it is suggested for keeping the outer channel free from human interferences. Therefore development of aquaculture projects between the Arakhakuda village and Satpara should not be taken into consideration. Similarly there are several low-lying areas between Nuapara island and Bajrakote area in the southern sector where prawn juveniles are available in large quantity. Those nursery grounds need protection and therefore all the available suitable brackish-water areas in that part of the lagoon should not be utilized for aquaculture projects. In order to avoid construction of embankments in the peripheral areas for aquaculture projects pen and cage cultures of brackishwater prawns/fish should be encouraged. This would help in maintaining the natural eco-balance in the lagoon.

Micro-level survey for rational utilization of brackishwater areas

Although only more than 5000 ha. brackishwater areas in the Chilka lagoon have been identified for aquaculture development, it is imperative to give a serious and judicious thought to conserve the natural environment of the lagoon while finally selecting the project sites for aquaculture. The micro-level survey which includes the ecological screening has to be conducted for selection of suitable sites for aquaculture which would not affect the natural eco-system of the lagoon. The Marine Products Export Development Authority (MPEDA) of Government of India and the Brackishwater Fisheries Development Agency, Puri-Ganjam are jointly engaged in such survey at present. The presently available areas of 5000 ha. may be further reduced when the micro-level survey will be completed in the next 2-3 years.

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Fishery Development of Chilka Lake

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Chilka lake is the largest brackishwater lagoon in the country and is about 906 sq kms in summer and 1165 sq kms in the rainy season. One outer channel of 35 km. long connects the lake with Bay of Bengal. The connection between the lake and the sea is now not effective for better tidal influence and stocking of the lake with shrimps, mullets and other economic species of fishes. Also siltaation at Magar Mukh, the gateway of the lake has badly effected the entrance of shrimps and fishes from the outer channel into the lake. There are about 114 fishermen villages inside the adjacent to this lake with a population of about 52000 fishermen who catch fish indiscriminately. Hence the fish production of the lake decreased considerably. By selective dredging of the lake, establishing the connection between the lake and sea, adopting effective methods of conservation and wide scale brackishwater culture along the inshore areas or the lake, the fish production can be increased substantially along with the improvement of the socio-economic conditions of the poor fishermen.

Introduction

Orissa has ample scope for the development of marine, estuarine and inland fisheries in the state. The estuarine areas of the state including Chilka lake is about 2978 square kilometers (Misra 1972). Chilka lake, the largest brackishwater lagoon in the country is about 906 square kilometers in summer and 1165 square kilometers in the rainy season (Misra, 1979). The lake is situated on the east coast of the country between latitude 19° 28' and 19° 54' N and longitude 85° 6' and 85° 35' E. The lake is pear shaped and is about 65 kms. in length and 16 kms in width. It is connected with Bay of Bengal by an outer channel which is about 35 kms. in length and is 365 m in width. The lake mouth is small and about 90-130 m in width. The lake is also connected with Rushikulya estuary by a canal called Palur canal. The average depth of the lake varies from 0.9 m to 2.5 m in summer and it becomes 2 to 3.5 m in rainy reason.

The fish production of the lake is decreasing due to ecological degradation. Fishery development of the lake is essential not only to increase the fish production but also to improve the socioeconomic conditions of the large number of the fishermen depending upon the lake.

Fisheries of the lake

The lake is generally divided into three sections to consider the fisheries of the lake. The southern sector lies in Ganjam district and extends from Palur to Khallikote and

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includes Rambha which is an important fish landing place. The central sector is quite vast and stretches from Khallikote to Kuhuri including Balugaon, the most important fishing landing centre. The northern sector lies between Kuhuri to Bhusandapur including another important fish landing centre Kaluparaghat and extends upto Satapara. The outer channel is connected with lake at a shallow place called Magar Mukh and this area lies between Nuapara, Satpara and Tua. The lake receives water from several rivulets of Mahanadi, the most important being river Daya. Besides during the rainy season it receives water by many streams pouring the rain water from Eastern Ghat Hills. There is considerable siltation in the lake particularly in the area of Magar Mukh.

The production of plankton varies from 0.03-0.27ml/litre. There are two peak periods, one dominant peak in April-August and the other in October to November. There are two minima, one in January and the other in August-September. The benthos biomass varies from 11 to 18.3 gm/square meter (Jhingran and Natarajan 1966). Algae are widely seen in the lake.

The fish production of the lake varies from 1098 to 2038 tonnes during the period from 1930-1945 (Mitra 1946). Devasundaram (1954) showed the annual fish production was 2859 to 3324 tonnes from 1948-52. Jhingran and Natarajan (1966) reported that the fish production varies annually from 2837 to 3334 tonnes. Fisheries Department, Government of Orissa shows that the fish production of the lake varied from 2601 to 4375 during 1958-1971. The present average annual fish production of the lake is considered to be 3000 tonnes. Prawns constitute about 28 percent of the total catch. Mulletts and catfishes form 19% and 12.5% respectively. The clupeoids, perches, threadfins and sciaenids comprise 12%, 11% and 6% respectively. Miscellaneous fishes constitute the rest 5%. The fish production of the lake varied from 25 to 45 kg per hectare during 1957-1965, the average being 35.35 kg. per hectare (Jhingran 1983).

The fishing methods of the lake are primarily net fishing, jano fishing and trap fishing. Net fishing is called Bahani and is practised throughout the year. It constitutes 50 to 60% of the annual fish production of the lake. Various kinds of drag net and gill nets and crafts like dugouts and boats are used for net fishing. Janos are large enclosures which are constructed with split bamboos in shallow regions to encircle the fish during September to October and fishes are caught almost every day. About 25% of the fish catch is done by Jano fishing. There are about 112 janos which are leased during August to February. The trap fishing is box type of basket made of bamboo with two or three openings for the entrance of fish and is used mainly to catch the prawns. Trap fishing is done either with or without a lead line. Trap fishing constitute about 19 to 32% of the total annual fish production of the lake. Dhaudi is larger box type trap with valves to prevent the escape of prawns while Baja is smaller and without any valve. The prawn khatties are about 70 in number and are leased from March to August. The Dian fisheries are uplands near jano areas and extend to about 100 to 200 yards from the shore towards the jano

areas and the nonfishermen catch fish in these areas. Utapani fishing is done both by fishermen and non-fishermen, in shallow water areas near the shore during the rain fall in the month of June. Crab fishing is done in Chilka lake by gill netting and also by traps.

Present status of the fishermen

There are about 114 fishermen villages inside and adjacent to the lake. The fishermen are about 52,000 and their economic condition is very poor. They are under the tentacles of the middlemen who exploit them in various ways. The middlemen generally advance money to the poor fishermen at the time of need and then take their catches paying less money and also charge high rate of interest. The fishermen catch fish indiscriminately from the lake for their own survival. Small, juveniles and adult fishes are caught mercilessly from the lake. Even the breeding fishes are caught and sold. There is absolutely no check to stop indiscriminate fishing.

Chilka fisheries is leased by Government in Revenue Department to the Central Fishermen Cooperative Marketing Society, Balugaon with a lease amount determined by Government. Generally every year there is an increase of lease amount by 10%. The Central Fishermen Cooperative Marketing Society takes the lease from government and subleases the various janos and prawn khatties to the primary fishermen cooperative societies. The primary cooperative societies are defaulters of paying the lease money in many cases. However, they show keen interest to take the lease of prawn fisheries due to the high price of the prawn. The middlemen enter clandestinely into the societies and advance the lease money so as to take the fish and prawns subsequently in less price. The fishermen are very much divided due to internal quarrelling and the role of primary cooperative societies and Central Fishermen Cooperative Marketing Society is not significant in any manner to take up either the marketing of the fish or to help the fishermen for their economic development. The existence of these societies has merely helped to get the lease of fisheries from the Government paying the lease money of the lake. The per capita income of the fisherman was about Rs. 600/- in 1974. Due to increase of fish price it has become about Rs. 1500/- now-a-days, but the poverty of the fishermen has not changed.

Scope of fishery development

The brackish water areas of the state has not yet been utilised scientifically for fish production (Misra 1979). There is considerable scope for the development of fisheries from the lake. The inshore regions of the lake are very suitable for brackish water fish farming. Misra (1986) stated that about 30,000 to 40,000 hectares of land areas can be obtained from brackish water fish farming along the margin of Chilka lake. Even sweet water fish can be cultured in some of the fish ponds as the salinity remains very low during the rainy season. Hence 30,000 to 40,000 tonnes of brackish water fish and prawns can be produced by brackish water culture from the lake. By widening the lake mouth, dredging the outer channel at suitable spots particularly in the area of Magar Mukh, deepening of the Palur

canal and observing conservation methods, the tidal ingression and stocking into the lake can be increased considerably. This will help in increasing the lake fishery to a great extent and will increase the fish production to a level of 4500 tonnes to 5000 tonnes. Fishery conservation methods such as regulating mesh size of various nets, imposing restriction on the catch size, prohibiting fishing in certain areas, adopting restricting fishing in some areas, complete banning of catch of the brood fishes and small size fry etc. must be adopted so as to increase the fish production of the lake. Strict penalty should be imposed so as to enforce the conservation methods. The fishermen of the area should be properly trained in pisciculture, nets, boats etc. and taught the method of induced breeding so that they can easily get the seeds of mullets, other fishes and prawns for brackish water fish culture. To check soil erosion, casurina plantation should be done. The brackish water areas should be leased to the local fishermen and people on long term basis and liberal financial assistance should be given. For quick development of fisheries, private entrepreneurs may be encouraged giving lease of land on long terms basis and institutional finance. The cooperatives should be strengthened and through the cooperatives land lease and financial assistance should be given. Defaulters should be strongly dealt so as to ensure discipline. The marketing of the fish should be done by the cooperatives and modern methods of fish transport and fish processing should be adopted for better quality. Technical assistance to the fishermen and cooperatives should be done by properly trained personnel. Possible steps should be taken to avoid dirty politics in the area so that the fishermen are not divided internally. The middlemen should be eliminated. If these steps are taken the socioeconomic conditions of the fishermen will rise considerably and the per capita income can be more than Rs. 10,000/-. Many ancilliary industries will grow along with fish production and will generate considerable employment for other people in the area.

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Growth of *Penaeus Monodon* in pens in Chilika lagoon and its Ecological significance

P. Ravichandran, T. Rajyalakshmi and S. M. Pillai*

Chilika, the largest brackishwater lagoon in India is characterised by high annual landings of penaeid shrimp and a variety of fin fishes. It is also a source of nutrient rich detritus forming an important part of the food web particularly of the shrimps.

Penaeus monodon, the jumbo tiger prawn, the most common species of capture fishery in the lagoon and the most important candidate species in the brackishwater culture system, was chosen for studies on growth and production in pens in Chilika lagoon. High average growth rate of 31g in two months was observed, in the split bamboo mat pens. The significance of the high growth rate observed is discussed in relation to the reported growth rates from various ecosystems, natural and man-made.

Introduction

Chilika, the largest brackishwater lagoon in India, is situated in Orissa at latitude 19° 20'—19° 54' N and longitude 85° 65'—83° 35' E, covering a waterspread area of 906 to 1165 square kilometer. The lake serves as the nursery ground for a variety of species of fish and prawn, and in an average a total of about 7000 metric tonnes of fish and prawn are landed every year. The catch/unit area is low, as is expected in large water bodies. The yield rates can be vastly increased if proper aquaculture technology is developed for the system. Cage and pen culture technology aims at utilizing unutilized and unmanaged water bodies for aquaculture.

Penaeus monodon, the jumbo tiger prawn, is one of the major species of prawn land in Chilika upto a tune of 300-400 m.t. per annum (Mohanty, 1985.). Being one of the fastest growing, hardiest and most euryhaline penaeid prawn, it is the most suitable species for brackishwater aquaculture and is widely cultured in various parts of India (Rajyalakshmi 1980a). Central Inland Fisheries Research Institute conducted a pilot study on the pen culture of *P. monodon* in Chilika lake (Rajyalakshmi and Ravichandran 1980, Rajyalakshmi 1982, 1984 a, b). The observations made during the study are presented in this communication in further detail with discussions on the comparative growth rates of *P. monodon* in various culture systems and the probable effect of the enclosure culture on the lake ecosystem. Merits and demerits of the enclosure culture versus semi-extensive culture being developed now along the northern and southern shorelines of the Chilika lagoon are also briefly discussed.

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Materials and methods

The logistics of pen culture programme

During 1980, when brackishwater aquaculture was being proposed/undertaken in site extensive programmes, the utilization of lagoons, the natural nurseries of marine prawns and fishes, were mooted without disturbing the existing ecology of the system. The design of practical and economically feasible set of culture management techniques was sought. The most logical one, under this set of circumstances, is the pen/cage system which should be practical, in view of the variety of organisms that are proposed to be brought under a common umbrella of brackishwater culture ecology. Much of the biological information on habitat preferences, food preferences, growth factors were still inadequate as compared to what can be obtained in a freshwater system.

How the confinement of stock will affect it stress-wise, which is reflected in its further adoption and growth is still to be ascertained. At the same time how the feed management is to be done is also to be ascertained. Further, which species adopt quickly and grow fast without yielding to stress related diseases and what will be the ultimate returns by way of yield are sought to be answered.

In this particular study answers to some more questions were sought such as, for example, adoption of these techniques by farmers, whether this system will cause pollution in the environment and condition of the stock, acceptance of product by the market and any legal hindrances to this technique if adopted in a largescale in the lagoon, whether on medium-or long-term basis and problems related to poaching.

The environment

A preliminary hydrographic survey was conducted in western coast along the central sector of the Chilika lagoon for a distance of 20km with the help of the State Department of Fisheries, Government of Orissa. A place near the village Gobapadar, 2 km from Balugaon, was chosen as the site of study. The bottom was sandy with less macro-vegetation. The area has no tidal action being located 46 km off from sea mouth. It has very few inputs from freshwater sources. The months of February to May were chosen with the assumption that freshwater run-off from land ward sources would be minimal and sudden and large fluctuations in ecological profile will be absent. Further, the best growth period for *P. monodon*, was during February-May as per earlier observations. The over all salinity, temperature profile of the non-tidal reaches of the lagoon have been recorded earlier (Jhingran and Natarajan 1969).

The pen

Two pens of 50 m² and 25 m² were used for the rearing of *P. monodon*. The smaller pen was provided with a 'fixed-net cage' open at the top, without any physical contact with the lake bottom.

The details of the pen design is presented in Fig. 1. The wall of the pen was made of split bamboo pieces of 2.5 m height, 6 mm wide and 4 mm thick interwoven with the dried stem of a creeper plant, locally called as *noi*. About 0.3 m of the mat was driven into the sand and a clear berth of 0.8m was kept above the highest high water level. The mats were kept in position by casuarina poles and bamboos staked at 1m intervals on alternate sides of the wall. Nylon netting material of 3 mm mesh was stitched with the wall of the pen, to prevent entry of pests and predators and escape of stocked prawns.

Stocking

Juveniles in two size-ranges were collected from various parts of the lake from traps and stick-net catches. The pen was stocked with prawns of average size of 112.4 mm/9 g and the net cage with juveniles of 56.3 mm/2 g, at arbitrarily fixed rate of 5 nos/m².

Feeding

The prawns were fed with pelleted feed made of prawn head powder, dried detritus and wheat flour in 1:3:1 ratio, once in three days at the rate of 10% body weight, owing to the high nutritive detritus available at the pen bottom. In the net cage the feeding was done daily.

Water quality at the experimental site was monitored continuously as per the standard methods (A.P.H.A. 1971). Sampling of prawns for monitoring the growth rate was carried out fortnightly. The prawns were captured by using traps and stick nets in pens and by lifting up the cage. Harvesting was also done in the same way.

Results

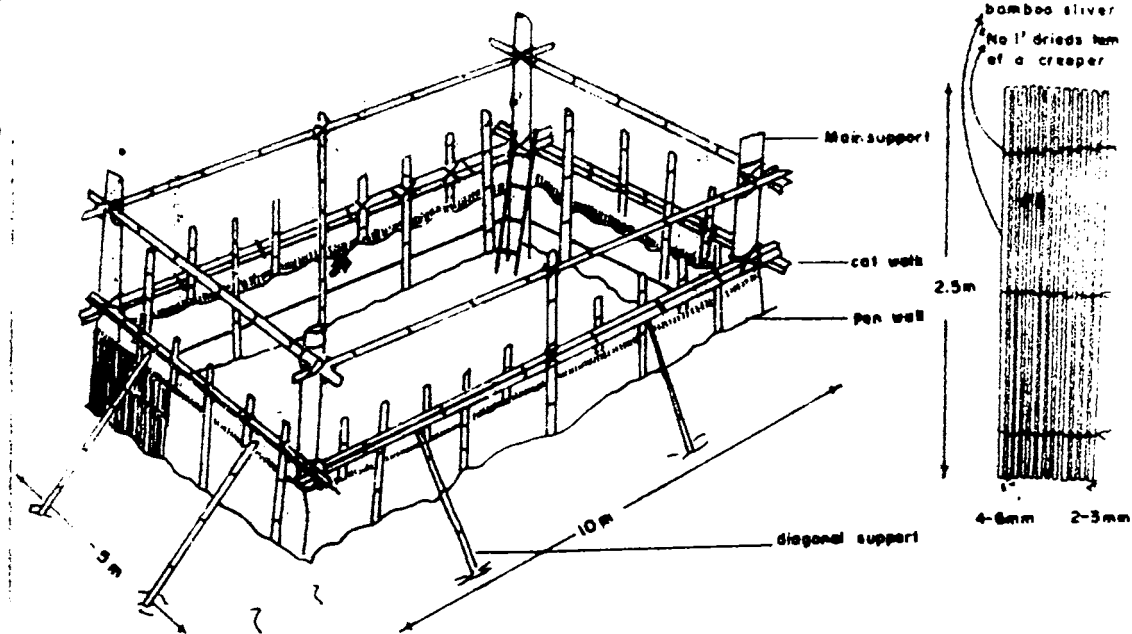
The details of the culture experiment is presented in Table. 1. During the culture period, the depth of the pen site ranged between 0.6 to 1.4 m. Daily variation in depth was minimal and was effected by the wind driven wave action. The average daily temperature gradually rose from 29.0° C to 34.5° C. Salinity also showed gradual rise from 7 ppt to

TABLE-1
Details of Culture of *Penaeus monodon*

Type of enclosure	Area	Stocking density	Average Size (mm)	Initial Wt. (g)	Average Size (mm)	Final Wt. (g)	No. of days	% Recovery
Pen	50m ²	5 nos/m ²	112.4	9	161.5	40	60	50
Fixed net cage	25m ²	5 nos/m ²	63.16	2	95.6	5.5	42	86.3

PEN-STRUCTURE

DETAILS OF PEN WALL



DETAIL SECTION OF PEN

DETAIL SECTION OF FIXED NET CAGE

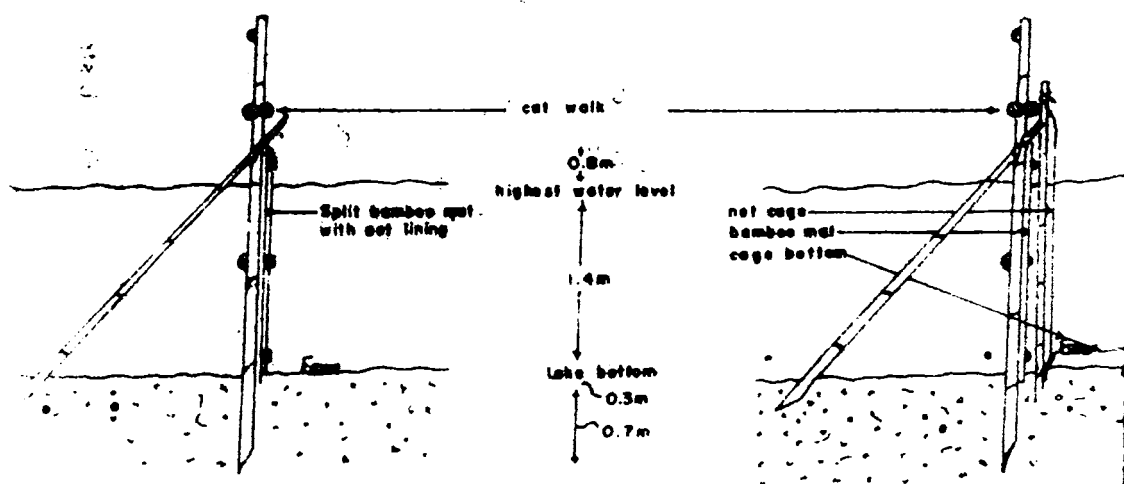
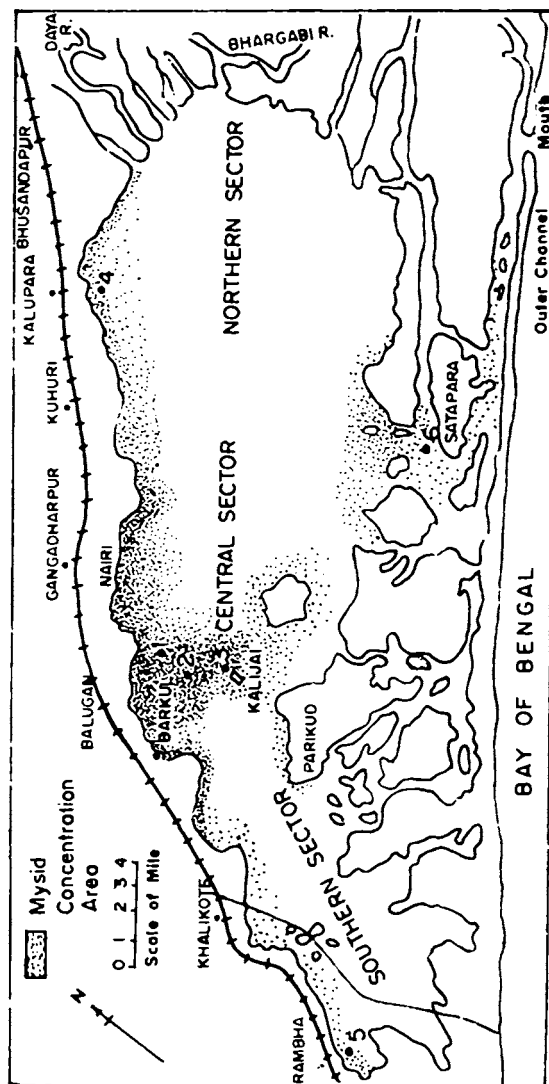


Fig.1. Details of Pen design and structure



Sampling Stations -- 1. Balugaon, 2. Chadheihaga, 3. Kalijai, 4. Kaluparaghat, 5. Rambha, 6. Satpara.
Fig. 1. Distribution and Abundance of Mysids in the Chilka Lagoon.

23 ppt. The minimal dissolved oxygen (DO) level in a day varied between 2 to 5 ppm during the culture period. Within the day the DO level fluctuated between 3.0 to 7.8 ppm. The plankton density ranged between 6 to 32 nos/litre, comprising mainly of copepods. The bottom biota showed enormous quantity of small gastropods and lamellibranchs upto a tune of 18,000 to 20,000 nos/m².

A growth increment of 49.1 mm/31 g in 60 days and 32.5 mm/3.5g in 42 days were observed for the large and smaller size groups, respectively. In the pen, an estimated production of 1000 kg/ha/2 months obtained. The growth curve in relation to temperature and salinity are presented in Fig. 2.

Discussion

Systems of enclosure culture and their suitability in Chilka lake

The use of cages and pens to rear the fish in large water bodies is an increasingly popular method of fish culture, involving relatively low initial costs and simple technology and management methods. These water based culture methods differ from land based ponds and raceways, in that these are open systems where interaction between the fish culture unit and the immediate environment can take place with few restrictions. Among cage and pen culture, when compared, a cage is totally closed on all sides or all but the top, whereas in the pen culture the floor of the lake or the sea is taken as the bottom. Thus pens are more close to the ecosystem in which they are sighted than the fixed or floating net cages. In the present study both types of culture were tried and it was observed that the growth of *P. monodon* is better in pens than in cages. But the retrieval of the species is easier with the net cages than in pens. Therefore for prawns, in general the net cage system is more suitable, irrespective of the productivity of the water body.

Like any other systems of culture, cage and pen culture are also classified as traditional, semi-intensive and intensive, depending on the degree of supplementary feeding. In highly productive ecosystem, such as that of Chilka lake, pen culture without any supplementary feeding can be attempted with greater success. But in cage culture of prawns, the system should be intensive, since the cultured species are not in contact with the bottom biota which form their natural feed.

Growth rate in different ecosystems

Under brackishwater semi-intensive pond culture conditions, (Rajyalakshmi 1980) a wide range of growth rates have been reported for *Penaeus monodon*. These rates are not strictly comparable since the stocking density site at stocking and the environmental conditions have a strong effect on the growth of the prawns. Further, with the improved management techniques, the growth rate has increased considerably. The average monthly length increments reported for *P. monodon* were 16.5 mm (Kubo 1956), 17.19 mm

(Delmendo and Rabanal 1956), 17.35 mm (Poernomo 1968), 17.55 mm (Verghese *et al.*, 1975), 36 mm (Alikunhi *et al.* 1975), 39 mm (Sebastian *et al.* 1978) and 37 mm/10.5 g. (Verghese *et al.* 1980).

In coastal freshwater ponds, *P. monodon* was reported to register average monthly growth rates of 27 mm/11.16 g (Pillai *et al.* 1986) and 25 mm/7.125 g (Rajyalakshmi and Chandra 1985).

Jhingran and Natarajan (1969) interpreted average monthly growth rates of *P. monodon* from different sectors of Chilka lake and the length frequency distribution during the period 1961-1965. It ranged between 1.20 mm to 20 mm.

In cage culture, Uma Maheswari (1983) observed a maximum growth rate of 31.25 mm/month at a density of 1 no/m² and 21 mm/month at 10 nos/m². In the present study an average monthly growth rate of 24.5 mm/15.5 g for the larger size groups in pens and 23 mm/2.5 g for smaller size groups in fixed net cages were observed. The high weight gain observed may be attributed to the nutrient rich detritus of the pen bottom in the Chilka lagoon.

Yield

In brackishwater pond conditions, under semi-intensive culture, a production of 1185 kg/ha/yr was reported by Verghese *et al.* (1980). Under intensive culture conditions with water flow-through and aeration, a production of 5000 kg/ha has been achieved by Liao (1977). Under completely controlled closed recirculatory system a production of upto 2 kg/m² has been reported by Forster and Beard (1974). Pen and cage culture conditions compare well with intensive culture system with continuous water exchange. Krishnan *et al.* (1983) have reported a production of 128 to 271 g/m²/3-4 months in floating cages and 40 to 216 g/m²/3-4 months in fixed cages, at varying densities and observed that higher densities yielded higher production but the growth was inversely proportional to the density. In the present study a production of 100 g/m²/2 months was achieved which when computed works out to 1000 kg/ha/2 months. Compared to the intensive culture system, the pen and cage culture are less cost-intensive utilizing the natural water and tidal current for water exchange and aeration and natural detritus, as feed.

Growth and carrying capacity :

Carrying capacity of the culture system essentially depends on the water quality maintenance. By increasing the carrying capacity of the culture system the density of the stock can be increased without interfering with the growth of the species. Verghese *et al.* (1980) observed in semi-intensive culture systems that whenever the density of the surviving prawns went above 1 no/m², the growth of the prawns were stunted. In intensive culture systems, the stocking densities could be increased upto 5 nos/m² without

affecting the growth rates (Liao 1977). In the cage culture studies, Uma Maheswari (1983) observed moderate growth rates with 10 nos/m² and very low growth rate with 15 nos m² indicating that higher densities above 10 nos/m² results in stunting of the cultured species, thereby resulting in poor yield. In the present pen-cage system, highest growth rates were observed with 5 nos/m².

Ecological parameters and growth rate :

Growth rate of the prawns were essentially dependent on the ambient ecological conditions. Temperature and salinity of the culture water act both directly and indirectly on the cultured species. Hence highly fluctuating temperature and salinity are not conducive for the growth of prawns (Rajyalakshmi 1980 b). Verghese *et al* (1980) and Chakraborty *et al* (1985) have observed that pre-monsoon growth of *P. monodon* is always better than the post-monsoon growth. Further low temperature reduced the growth rate through reduced metabolism. It was generally observed that temperature above 26°C and a salinity range of 10-15 ppt. is found to be optimal for the growth of *P. monodon*. The present experiment was conducted in ecologically stable summer, during which there was a gradual increase in the temperature and salinity without any sudden fluctuations.

The low oxygen values in the pen water indicates source of pollution, probably from the decaying vegetation all-round. The lake itself has a dense growth of vegetation which is constantly disturbed, broken up and even removed by the heavy fishing activity. This results in heavy detrital load. Constant removal of this mass would be needed to create higher or optimal oxygen budget. This feature of low oxygen saturation has to be critically viewed. The flow of freshwater in monsoon might result in haloclines and is a real critical factor for the pen stock. When such conditions occur, metabolites may start to decompose at the bottom and result in oxygen depletion below critical level.

Environmental impact :

Pen and cage culture in natural water bodies, may have serious impact on the environment, when taken up in a large scale. Hence proper planning should be given before expanding the technology to a greater scale. Probable environmental impacts are discussed briefly here.

Pens and cages affect the water bodies both by their physical presence at a site and by the changes they can induce in the physical, chemical and biological characteristics of the water body through the method of culture and species used.

Cage and pen structure exert considerable impact on water currents, depending on the flow rate, water density, enclosure size and shape, mesh size, material and degree of flowing. Significant reduction in flow would cause sedimentation of large denser particles in the immediate vicinity of the cages and pens and thereby disrupting benthic communities. Further, the reduction in water flow may seriously affect the prawn culture operation as well.

Enclosure culture systems are actually sub-component of the lake or estuary in which they are located, and the interactions between the environment inside and the environment outside the enclosure occur with little restriction and so changes in one part of the ecosystem invariably affects all the other parts to a greater or a lesser degree.

Depending on the type of culture employed, the nutrient status of the original ecosystem will be affected. With traditional system of culture there will be nutrient loss from the ecosystem through harvested fish and with intensive culture system, where all the requirements of food will be met from outside; there will be nutrient gain in the form of unconsumed food, faecal matter and other wastes. The former will lead to nutrient depletion while the latter will result in organic pollution.

Environmental impact of extensive culture systems :

In the recent years, extensive areas on the fringes of Chilka lake are being converted into brackishwater ponds under governmental programme. The excavations are being undertaken on areas which were originally flooded during post-monsoon period. This will have a strong impact on the ecology of the lake. With these operations the shallow and grass covered juvenile nursery grounds will be lost leading to a general decline in juvenile population.

Further, extensive implementation of these programme will result in serious obstructions for the flood water movement and sedimentation rate near the pond embankments leading to eutrophication of the lake.

These ponds are of completely enclosed nature with rainwater as the only source. With this type of operation, the soil salinity will be leached and the water will become completely fresh within a few years, as it happened in Bakkhali fish farm (Pillai *et al.* 1986). This will render the ponds useless for *P. monodon* culture. Hence the technical advisers of the programme should give a serious thought as to whether it is worthwhile to interfere in such an ecosystem for a short-term profit in prawn culture. Alternatively, the ponds should be designed in such way that water exchange can be undertaken as and when necessary.

Recommendations

From the foregoing observations and discussions it is clearly evident that introduction of pen or cage culture of *P. monodon*, in Chilka lake will greatly enhance the yield per unit area, with better utilization of space. But large scale implementation of this technology should be judiciously undertaken with great care so as not to disturb the existing ecosystem.

Besides prawns, fishes also can be cultured under this system. The most suitable species are *Lates calcarifer*, *Mugil cephalus*, *Etroplus suratensis*, *Chanos chanos*, to mention the four most marketable types. Although, all these species have been known to adopt to

a wide range of salinity conditions, sudden fluctuation might cause severe stress. Therefore six months short-term culture can be chosen during the period when there is least disturbance in the lake ecology.

Greater in-depth survey is needed for locating pens/cages keeping in view of the biological information on the species to be cultured.

In regard to *P. monodon*, size groups from postlarvae to juveniles of 3-5 g can be chosen for stocking. The major criterion should be that the optimal oxygen level of over 3 ppm is always maintained at the pen/cage site.

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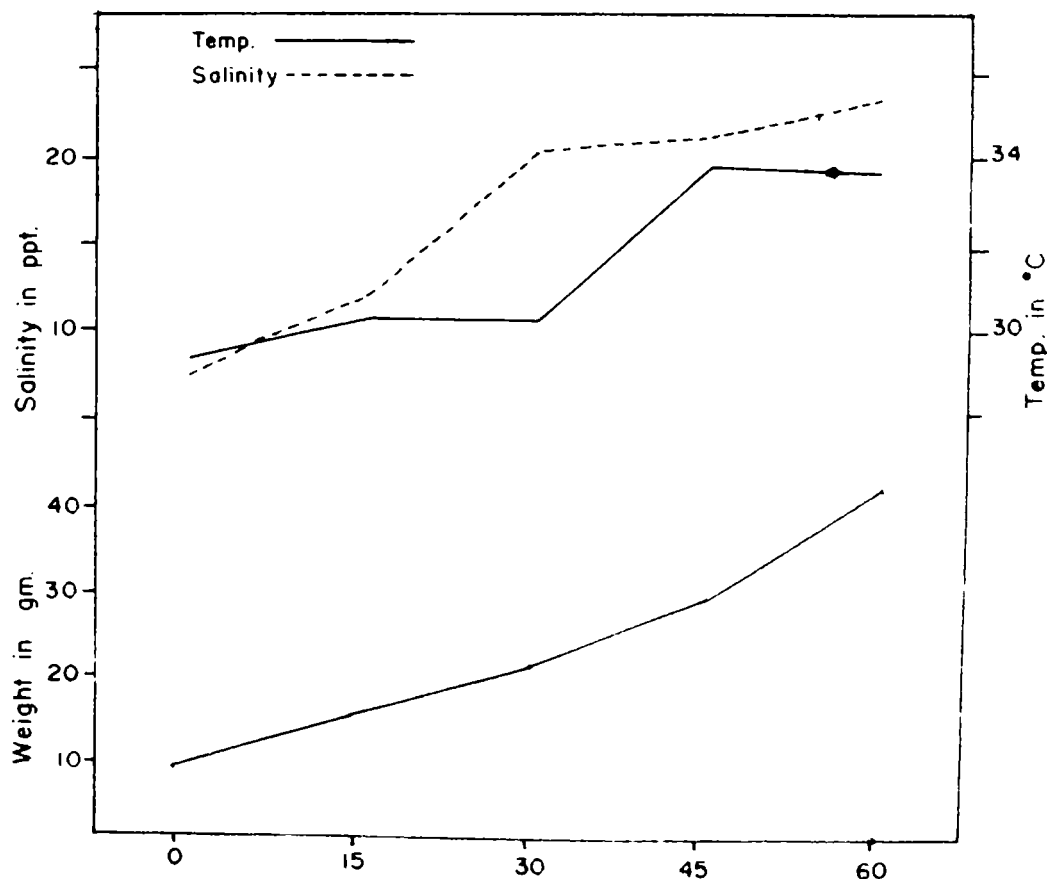


Fig.2. Growth of *Penaeus monodon* in pen relation to temperature and salinity.

Some observations on the occurrence of Mysids in the Chilka Lagoon

P. N. Patnalk*

Chilka, the largest blackishwater lagoon in the country offers ideal ecological conditions for the occurrence and abundance of growth of eurihalyine species of Mysids. Available species of Mysidacea, their seasonal and locational abundance, influence of physico-chemical parameters of brackishwater on their occurrence in the lagoon and their commercial use as a high class protein-rich feed in brackishwater prawn culture and management of prawn hatchery are discussed. Growth and survival of Mysids as studied in the laboratory have been reported.

Introduction

The Mysids occurring in the Chilka lagoon in considerable quantity form one of the important natural food items for prawns and many brackishwater fishes. Not only as a source of food for the local fishermen but also as a source of raw material for preparation of suitable feed for larval feeding in the modern prawn hatcheries, it has drawn the attention of the fishery workers in the recent years. Hameed Ali (1980) developed tissue suspension feed prepared from crustacean meat for successful larval feeding in the prawn hatchery. Since then the Mysids have been considered to be one of the important raw materials for preparation of such feed for management of prawn hatcheries. Attempts have been made in the present work to make preliminary observations on their distribution and seasonal abundance in the Chilka lagoon.

Material and methods

Regular weekly samples of Mysids from five sampling stations in the Chilka lagoon (Kaluparaghat, Balugaon, Chadheihaga, Kalijai and Rambha) were collected simultaneously during the period from November, 1978 to January, 1981. Besides, periodical samplings alongwith prawn seed prospecting was also done at Satpara during the period. Mysids were collected alongwith plankton by using standard plankton net made of bolting silk material and filtering fifty litres of the surface water between 07.30 and 08.30 hours. Casual samples were also collected from the outer channel of the lagoon.

Abundance of Mysids was estimated as percentage of total zooplankton. Physico-chemical parameters of the lagoon water at the sampling stations were studied by standard methods described by Jhingran *et al.* (1970). Growth and survival study was made in the

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Laboratory by glass jar experiments using natural brackishwater from the lagoon. The segregated biomass was preserved in seven percent formalin for later study.

Results and discussions

Of the five species of Mysidaceae now known from brackishwaters in India four occur in the Chilka lagoon. Those four species of Mysidacea of Chilka lagoon as recorded by Tattersall (1915) are :

Rhopalophthalmus egregius Hansen, *Macropsis orientalis* W.M.T., *Potamomysis assimilis* W.M.T., *Gastrosaccus muticus* W.M.T., No additions to these four species have been observed during the present study.

Mysids in the plankton net collections dominated at Kalijai, (66.23%) Chadheihaga (56.87%) and Balugaon (42.07%) for the entire period of observations (Table-1). Observations from Kaluparaghat station showed an average collection of 31.46 per cent and the lowest collection of 5.31 per cent was recorded from Rambha Station in the southern sector of the lagoon. This indicated that the Mysids along the western bank (Kaluparaghat to Barkul) were available in more abundance than the main area of the lagoon. Between Balugaon and Barkul, where moderate salinity (9.88-12.96%) prevailed round the year (Table 1) three of the four Masidacea (*Rhopalophthalmus egregius*, *Macropsis orientalis* and *Potamomysis assimilis*) were very much abundant (Fig. 1). They were less abundant in the southern sector and the main area of the lagoon. It was also observed during the study that the Mysids were also available in considerable quantity near Satpara and in the outer channel but their concentration was much less. The shooting net collections of prawn post larvae/juveniles near Satpara showed that the Mysids constitute 40-90 per cent of the total collections, particularly when the post-larvae/juveniles of *Penaeus indicus* dominated. This is probably due to the reason that both the white prawn seed (*P. indicus*) and Mysids prefer same type of planktonic food and other ecological conditions.

The Mysidacea of the Chilka lagoon form a minor fishery, mainly during April-August and also in late winter in lesser magnitude. Their abundance reaches peak just before on-set of monsoon. Fishermen from the shore-line villages of the lagoon, mainly along the western bank collect the Mysids actively during May-June through July for their consumption.

The Mysidacea collected during the study were within the length range of 2-9 mm and most of the matured specimens with brood pouches were observed within the length range of 7-9 mm. Brood specimens occurred in more numbers in the collections during full moon and reduced to the minimum in the new moon. Total number of eggs found in the brood pouches ranged from 7-15. Mixed size groups and brood specimens with eggs were always noticed in the collections which indicated that the breeding of the Mysidacea in the Chilka lagoon was almost a continuous process.

Table—1

**Abundance of Brackishwater Mysidacea in the Chilka Lagoon and
the Physico-Chemical Features of the Lagoon Water at Collection Stations.**

	COLLECTION STATIONS				
	Balugaon	Chadheihaga	Kalijai	Kalupara	Rambha
Mean % of Mysids in the zoo plankton.	42.07 (0—71.15)	56.87 (22.48—78.57)	66.23 (2.01—94.65)	31.46 (0—100)	5.31 (2.16—15.96)
Month of maximum abundance.	May	July	November	September	January
Month of minimum abundance.	September	September	January	January	May
Size range (mm)	4—7	2—8	2—9	4—9	1—5
Physico-chemical parameters					
Mean water temperature (°C)	25.86 (20—31)	27.15 (23.5—31.5)	28.1 (24—31.5)	26.75 (23—29)	25.33 (20—28)
Mean transparency (CM)	60.64 (30—92)	N.R.	77.5 (43—129)	29.75 (12—90)	43.83 (30—70)
Mean salinity (ppt)	10.16 (5.2—19.3)	9.88 (3—26.7)	11.32 (3.6—24.7)	2.59 (0.1—9.4)	12.96 (5.6—19.3)
Mean dissolved Oxygen	5.2 (3.1—5.0)	5.0 (2—7.6)	4.55 (2—7.8)	4.53 (1.4—8.5)	5.59 (1.7—8.3)
Mean pH	8.2	8.31	8.28	8.18	8.22
Mean CO ₂	4.9	5.0	2.4	1.26	8.86
Mean total alkalinity (ppm)	65.5 (59—72)	78.22 (65—111)	91.31 (46—113)	77.6 (40—122)	102.13 (84—135)

Figures in parenthesis indicate minimum and maximum values.

Vertical migration of the Mysids was distinctly observed throughout the study period which was governed by the light intensity. In the early morning hours the swarms of Mysids were seen on the surface and they moved down as the intensity of sun light increased. Similarly, the concentration sharply decreased with the increase of water

turbidity. Therefore, during monsoon, when the discharge of turbid flood waters into the lagoon increased, their abundance suddenly decreased. Their abundance in the lagoon was also observed to be minimum when the mean water temperature increased beyond 30°C. The multiplications of the Mysidacea was greatly reduced in the peak monsoon when the salinity dropped to the minimum. Their peak abundance in summer, particularly just before monsoon rain indicated their preference towards higher salinity. When the cloudy weather with drizzlings continues for few days in the beginning of the monsoon, thick swarms of Mysids appear along the shallow waters and are caught in large quantities by the local fishermen. During such weather conditions the swarmings were observed in larger concentration where the grasses were available in the marginal areas.

The laboratory experiments conducted in the glass jars using natural lagoon water showed that the young Mysids attained the mean size of 4 mm within 11 days after hatching. Although the water temperature at all the sampling stations ranged from 20-31.5°C, the mean water temperature ranged from 25.33-28.10°C (Table-1).

Since the present work is of preliminary nature it is suggested that a detailed study be taken up on the biology of Mysidacea of the Chilka lagoon alongwith quantitative estimates which would throw light on its commercial utilization as a high grade animal protein feed in commercial prawn farming.

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Fig: See page - 47

Mosquito fauna of Chilka lake area, Orissa

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A total of 22 species of mosquitoes belonging to five genera viz., *Anopheles*, *Aedes*, *Armigeres*, *Culex* and *Mansonia* were identified during the survey. Seven anophelines viz., *An. fluviatilis*, *An. jamesii*, *An. maculatus*, *An. splendidus*, *An. stephensis*, *An. sundaicus* and *An. theobaldi* recorded in the past, around five decades ago were not found. This was mainly due to various ecological changes in the area.

Introduction

Chilka lake in Orissa, the largest brackish water lagoon of India, has been the venue of many investigations on mosquitoes because of the role of *Anopheles sundiacus* Rodenwaldt, 1926 in malaria transmission (Rao 1984). Survey of mosquito fauna of Chilka lake area dates back to 1912, when Fry (1912) reported five anopheline species from the localities. Among others who had investigated the area before second world war were Sarathi (1932), Senior White and Adhikari (1939) and Covell and Singh (1942). Since then there has not been any systematic survey on the mosquito fauna of Chilka lake area. Further, during the past four decades due to lot of ecological changes in the area, it is likely that some of the mosquito species listed by the above authors would have disappeared and hitherto unreported species would have immigrated. This phenomenon has already been observed in other parts of Orissa (Dash *et al.*, 1984) and India (Rajgopal, 1976 and Kalra, 1978). Here an attempt is made to study the current species composition of mosquitoes in the Chilka lake area.

Materials and methods

Intensive and extensive surveys were carried out in the localities situated inside and on the bank of Chilka lake. The areas surveyed were Krushna Prasadgarh (Parikud), Samal island (inside Chilka lake), Balugaon, Sikharpadar, Pathara, Kanaka Kuhudi, Soran, Sundarpur, Mangaljodi and Badkul. Indoor resting adult mosquitoes were collected with the help of aspirator tube and mechanical aspirators (Hausherr's machine works, U. S. A.) and identified species wise. Larvae found in Chilka water were collected and reared in the laboratory. The adults thus emerged were identified and recorded. Keys of Christophers (1933), Barraud (1934) and Rao (1984) were used for species identification. The survey was carried out through out the year covering all the seasons during 1986-87. The abdominal conditions of the identified mosquitoes were examined and graded as unfed (UF), fullfed (FF), half gravid (HG) and gravid (G).

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Table-1

• **Number of Mosquitoes collected and their Abdominal Conditions**

Sl. No.	Name of the species	Total no. of mosquito	Total Male	Total female	Abdominal condition			
					UF	FF	HG	G
1.	<i>Anopheles aconitus</i>	45	—	45	11	31	3	—
2.	<i>Anopheles annularis</i>	362	—	362	91	217	40	14
3.	<i>Anopheles barbirostris</i>	12	—	12	—	12	—	—
4.	<i>Anopheles culicifacies</i>	106	—	106	40	33	33	—
5.	<i>Anopheles 'hyracanus' group</i>	524	—	524	78	355	89	2
6.	<i>Anopheles jeyporiensis</i>	3	—	3	—	3	—	—
7.	<i>Anopheles karwari</i>	2	—	2	—	2	—	—
8.	<i>Anopheles pallidus</i>	3	—	3	2	1	—	—
9.	<i>Anopheles philippinensis</i>	9	—	9	6	3	—	—
10.	<i>Anopheles ramsayi</i>	9	—	9	6	3	—	—
11.	<i>Anopheles subpictus</i>	1544	27	1517	345	452	631	89
12.	<i>Anopheles tessellatus</i>	2	—	2	2	—	—	—
• 13.	<i>Anopheles vagus</i>	413	21	392	57	153	130	52
14.	<i>Anopheles varuna</i>	19	—	19	—	13	6	—
15.	<i>Aedes aegypti</i>	3	—	3	—	3	—	—
16.	<i>Armegeris theobaldi</i>	6	—	6	2	4	—	—
17.	<i>Culex epidesmus</i>	6	—	6	3	3	—	—
18.	<i>Culex gelidus</i>	126	—	126	6	84	36	—
19.	<i>Culex quinquefasciatus</i>	787	40	747	167	374	198	8
20.	<i>Culex 'vishnui' group</i>	656	9	647	102	365	178	2
21.	<i>Mansonia annulifera</i>	205	—	205	51	117	37	—
22.	<i>Mansonia uniformis</i>	88	4	84	27	37	17	3
•	Total	4924	101	4823	990	2265	1398	170

Table-2

Mosquito Fauna of Chilka Lake Area During 1937-1942 & 1986-1987

1937-1942	1986-1987
(Senior White and Adhikary 1937; and Covell and Singh, 1942)	
<i>Anopheles aconitus</i> Donitz.	<i>Anopheles aconitus</i>
<i>Anopheles annularis</i> v.d. wulp.	<i>Anopheles annularis</i>
<i>Anopheles barbirostris</i> v.d. wulp.	<i>Anopheles barbirostris</i>
<i>Anopheles culicifacies</i> Giles	<i>Anopheles culicifacies</i>
<i>Anopheles fluviatilis</i> James.	—
<i>Anopheles 'hyrcanus'</i> Giles group.	<i>Anopheles 'hyrcanus'</i> group
<i>Anopheles jamesii</i> Theobald.	—
<i>Anopheles jeyporiensis</i> James.	<i>Anopheles jeyporiensis</i>
<i>Anopheles karwari</i> (James)	<i>Anopheles karwari</i>
<i>Anopheles maculatus</i> Theobald.	—
<i>Anopheles pallidus</i> Theobald.	<i>Anopheles pallidus</i>
<i>Anopheles philippinensis</i> Lud.	<i>Anopheles philippinensis</i>
<i>Anopheles ramsayi</i> Covell.	<i>Anopheles ramsayi</i>
<i>Anopheles splendidus</i> Koidzumi.	—
<i>Anopheles stephensi</i> Liston.	—
<i>Anopheles subpictus</i> Grassi.	<i>Anopheles subpictus</i>
<i>Anopheles sundaicus</i> Rodenew.	—
<i>Anopheles tessellatus</i> Theobald.	<i>Anopheles tessellatus</i>
<i>Anopheles theobaldi</i> Giles.	—
<i>Anopheles vagus</i> Donitz.	<i>Anopheles vagus</i>
<i>Anopheles varuna</i> lyengar.	<i>Anopheles varuna</i>
	<i>Aedes aegypti</i> (Lin)
	<i>Armegeres theobaldi</i> Barraud
	<i>Culex epidesmus</i> (Theobald)
	<i>Culex gelidus</i> Theobald
	<i>Culex quinquefasciatus</i> Say
	<i>Culex vishnui</i> group Theobald
	<i>Mansonia annulifera</i> (Theobald)
	<i>Mansonia uniformis</i> (Theobald)

Results and discussion

As many as 4924 mosquitoes belonging to 22 species of five genera viz., *Anopheles*, *Aedes*, *Armegeres*, *Culex* and *Mansonia* were collected during the survey. Number of mosquitoes belonging to each species along with their abdominal conditions are presented in Table 1. The anopheline mosquitoes constituted 61.8% of the total mosquito population. *An. subpictus* was found to be the dominant species. The occurrence of *An. subpictus* was 31.3 and 50.6% of the total mosquitoes and anophelines respectively. Among anophelines, *An. 'hyrcanus'* group followed *An. subpictus* in numbers. *Cx. quinquefasciatus* constituted 15.98% of the total mosquitoes and 41.92% of culicines. It was followed by *Culex 'vishnui'* group. Species like *An. jeyporiensis*, *An. karwari*, *An. pallidus*, *An. tessellatus*, *Ae. aegypti*, *Arm. theobaldi* and *Cx. epidemus* were of rare occurrence.

The fullfed and half gravid mosquitoes were 46.96 and 29.98% respectively. This indicates that most of the mosquitoes were indoor resters.

In the past, one of the most careful and intense surveys of mosquitoes was that carried out by Covell and Singh (1942) in Chilka lake area for three years during 1939-42. They reported 17 species of anophelines. This survey was carried out after the study of Senior White and Adhikary (1939) who recorded 19 species of *Anopheles*. Covell and Singh (1942) reported one additional species and three *Anopheles* recorded by Senior White and Adhikary (1939) were not encountered by them. As would appear from Table 2, a total of 21 species of *Anopheles* were known till 1942 and prevalence of other mosquitoes were not known in the Chilka area till the present study. Seven anopheline species recorded earlier viz., *An. fluviatilis*, *An. jamesii*, *An. maculatus*, *An. splendidus*, *An. stephensis*, *An. sundaicus*, and *An. theobaldi* were not found in the present survey. This was mainly, may be because of the ecological changes in the area, due to various developmental activities and rapid deforestation.

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Vegetation and Flora of the Chilika lagoon

G. Panigrahi*

The paper outlines some of the chief attributes of the Chilika lagoon to justify the landscape as a "Queen of Nature" and urges upon the Government to manage and conserve it as a national heritage.

The location and area of the lake and its surrounding areas are briefly discussed and the vegetation and flora of collected/reported to-date are analysed and a comparison of the vegetation and flora met within five sectors of the lagoon and of the flora characteristic of the vast expanse of the brackish water mass, is instituted. The variations met within floristic composition from the sandy shore to the top of the Ficetum in the Barkuda island, are also noted. An appendix listing about 150 species of vascular plants, with correct nomenclature and notes on ecology and locality is also provided to help conservationists to focus attention on selection of species, not only for afforestation programmes, but also to provide nesting/perching sites to the migratory birds.

Introduction

Chilika lake is the pride and glory of Orissa, and has stirred the imagination and admiration of the poets and naturalists alike, over centuries. The poet laureate of Orissa, Radhanath Ray was inspired by its grandeur and beauty to compose the *Kabya* entitled "CHILIKA" wherein he referred to the '*Maralamalini Nilambu Chilika*' as the most precious treasure-house (*Gantaghar*) of Utkal, and *Utkalamani* Pandit Gopabandhu Dash composed his famous patriotic anthem during his train journey across Chilika. Both the poets gave the graphic details of the natural landscape of the largest inland brackish watermass of India, next of Asia. 'KALIJA', the lyric composed by Pandit Godabarish Misra, overwhelms our emotions with pathos and sympathy for the father-son who survived and for his daughter-companion, who died, as the boat capsized, overtaken by gusty storm across Chilika beyond its island, *Kalijai*. These three compositions have endeared Chilika to us all, so much so that we consider it as one of our proud heritage of the state of Orissa.

The vastness of the lake, with a waterspread area of 906 and 1165 square kilometers during summer and winter respectively, its sandy creeks and water-channels barricading it from the Bay of Bengal, its rich scenic beauty, its economic potentials as a reservoir of fish and birds, both indigenous and migratory is unique in its character.

The Chilika lagoon is situated within 19° 28' - 19° 56' N and 85° 6' - 85° 86' E and stretches over 70 kms along the north-east to south-west direction and is about 30 kms. in

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its widest part. Its major portion lies in the Puri district, with only a minor portion bordering upon Rambha in the Ganjam district. The outer channel runs parallel to the Bay of Bengal over a distance of 45 kms, from Ganjam Canal to the mouth of the Chilka lake, near Arakhuda and is a sandy stretch with 0.25 to 1 km in width. The lagoon is studded with a number of emerald green islands, with such colourful names, as 'Honeymoon Island', 'Breakfast Island', *Kalijai*, a place of pilgrimage and *Nalabana*, a pasture swamp for the cattle and natural landing site for hundreds and thousands of migratory birds. The other islands bordering upon the Bay of Bengal contain villages and hamlets.

Vegetation and flora

Champion and Seth (1968) and Panigrahi (1983) do not specifically refer to the vegetational type met with in the Chilika lagoon, although we may refer the strand vegetation met with in sandy stretches along the Bay of Bengal to their sub-group 4 A-Littoral Forests. The most characteristic species is the tall evergreen but very light foliated *Casuarina equisetifolia* which almost forms a pure fringe on sandy beaches and dunes along the sea-face. Numerous shrubs, and where the undergrowth is light, maritime grass *Spinifex squarrosus* and surface creepers, such as *Ipomoea pes-caprae* are conspicuous, binding the sand.

Annandale (1920) and Biswas (1923) studied the phanerogamic and algal flora of the Chilika lagoon, respectively. Annandale who visited Barkuda Island and the adjoining Chheriakuda Island in the summer and autumn of 1919 for three months (August-October) and again, in December 1919 and April, June, September 1920, studied the vegetation, physical structure, the palaentology and climate of the area.

Barkuda or Barakuda island, situated to the south-western extremity of the lake, is not more than half-a square mile in area and lies within the range of insects of feeble flight and also many seeds from the adjoining mainland. It lies within the isothermal lines representing 27°—28° C and within the southwest monsoon. Its climate is tropical; although only 1.6 to 3 km away from the mainland, it has a more equable climate because of its insular position. The average annual rainfall at Rambha is nearly 1137 mm. Yet, the air is damp from July to October and the rainfall is sufficient to soak the scanty soil and reduce it to mud for some days at a time. The direction of the wind from April to August is south-west or S. S. W., but the heaviest storms are from the south-east or east.

The physical structure of the island is very simple, the surface nowhere rises above 10-13 m above MSL. The whole area is rocky and stony with scanty soil cover of red soil, but on the foreshore, it is rocky and stony without any soil. The whole island is built of sedimentary rocks, consisting of garnett-bearing quartzites with or without silimanite and belong to the khondalite series. The rock of Barkuda is non-fossiliferous, but the soil

of its interior and the sand of its shore contain molluscan shells that may be classed as subfossil. Annandale mentions a few species occurring as relicts of an extinct race still surviving in the Outer Canal.

The vegetation of Barkuda island consists mainly of large trees, shrubs and thick-stemmed creepers, which become luxuriant in the rains. There are no epiphytes, no tall grasses, reeds or bamboos, no palms, no screw pines, aroids or orchids, only a few or no parasites, ferns, mosses or liverworts. The greater part of the island is occupied by a ficetum or fig-jungle, the dominant of which is *Ficus benghalensis* L., the Banyan. The greater part of the island is a scrub, comprising *Glycosmis pentaphylla* as the most dominant scrub and *Cissus quadrangularis*, the most common climber. *Azadirachta indica* and other species of *Ficus* without spreading habit occupy these thickets, where the rock substratum is covered by a thin layer of soil. Parts of the island where the soil is sandy and gravelly, not rocky, are occupied by *Cassipourea ceylanica* (a mangrove species) and *Crataeva magna* and *Azadirachta indica*. No *Ficus* spp. or *Glycosmis* occur in such situations. At the high flood level, *Pongamia pinnata* forms almost an unbroken ring around the island. *Jatropha heterophylla*, *Annona squamosa* and *Opuntia* spp. occupy large areas as naturalized elements.

Comparison of the vegetation and flora of the Barkuda with those of the other islands and headlands of the Chilika lagoon.

Very little information is available about the flora of the shores and other islands of the Chilika lake. The islands are of several kinds, differing greatly in formation and vegetation and one can recognise at least five types between them :

- (i) In the Outer Channel of the lake-system, the islands are mere banks, often submerged, completely or in part, in the flood season. The flora consists of a few species of sedges and grasses, which sometimes form a coarse turf and occasionally of *Crataeva magna* rising only to a few metres in height.
- (ii) The largest island, the Nalabana, is in fact a flat mud bank, once occupied by a pure formation of *Phragmites karka*, is now a swamp, from which *P. karka* has practically disappeared due to over-grazing and other biotic factors.
- (iii) A characteristic feature of the scenery of the Chilika lake is the presence of small conical hills formed of gneiss, such as the Ganta Sila at the south-western end of the lake. *Bauhinia tomentosa* with beautiful pale-yellow flowers, forms irregular thickets among the blocks of rock on steeper slopes. *Cassia occidentalis*, *Pavonia odorata*, *Helecteres isora*, *Argyrea nervosa* and *Ipomoea sepiaria*, *Bambusa arundinacea* and *Phragmites karka* are found here along with many herbaceous grasses. Creepers of the Convolvulaceae and Cucurbitaceae are abundant, along with *Cassipourea ceylanica* and *Euphorbia terilis*.

- (iv) A large number of islands are low and undulating and consist of alluvium and lie close to the shore and frequently become peninsulas as the waters of the channel dry up. These islands are mostly inhabited by fishermen, who have contributed largely to the change of vegetation and flora because of large scale cultivation. *Ficus* spp., *Tamarindus indica*, *Helecteres isora*, *Martynia diandra*, *Barleria prionites*, *Mucuna pruriens* and *Cipadessa fruticosa* are the principal components of undisturbed habitats.
- (v) The islands of Barkuda and Chheriakuda represent the fifth type, studied in detail by Narayanswami and Carter (1920). The genera *Bauhinia*, *Bambusa*, *Phragmites*, *Cassia*, *Mucuna*, *Cipadessa*, *Pavonia*, *Helicters*, *Argyreia*, *Martynia*, *Barleria* and *Pandanus* are altogether absent from these island group.

Here, we may trace the vegetation from the foreshore to the upper regions of these two islands :

- (a) It is generally rocky and gravelly or sandy and no where muddy. Filamentous algae, *Potamogeton pectinatus*, *Salvadora persica*, *Barringtonia acutangula*, *Mimusops hexandra*, *Canthium parviflorum* etc. grow among rocks above the high flood level. The vegetation of the sandy and gravelly foreshore is much less conspicuous. *Cressa cretica* and *Ipomoea pes-caprae* occur occasionally, the grasses and sedges being more common. *Sueda nudiflora* and *Cressa cretica* immerse from below the rocks, and *Cynodon dactylon*, *Daetura metel*, *Cyperus compressus* and *Coldenia procumbens*, some of them as introduced elements borne by air agency from the mainland. *Schoenoplectus littoralis* (*Scirpus littoralis*) occurs on the muddy foreshore in many places, apart from muddy foreshore of Chheriakuda.
- (b) *Pongamia* zone : *Pongamia pinnata* forms a ring above the high flood level, about 3-to 4-tree deep, associated *Azadirachta* and *Crataeva*. Dense masses of creepers and liaras, *Derris trifoliata*, *Acacia intzia* and *Capparis roxburghii* overwhelm the neem trees and *Crataeva*. *Cassytha filiformis* sometimes parasitises the neem tree. *Pongamia* is singularly free from climbers; in stony areas *Salvadora persica* replaces the neem and *Crataeva*. *Potamogeton* and filamentous algae often form festoons on the lower submerged branches of *Pongamia pinnata*.

In the sandy areas of the *Pongamia* zone, a distinct association of shrubs and trees occurs, but *Ficus* sps. are completely absent, Neem *Crataeva*, *Lannea coromandelina* and *Albizzia odoratissima* replace *Pongamia* in such situations. Scattered plants of *Cassipourea ceylanica* and *Euphorbia nerifolia* are rather more common. *Opuntia* occurs as a few clumps here and there. *Dioscorea* and *Cissampelos* are the common climbers here. Masses of *Jatropha heterophylla* and *Oldenlandia heynii* form a regular border to the clumps of *Cassipourea*.

- c) *Ficetum* : Seven species of *Ficus*, *Azadirachta indica*, *Alphonsea scleroscapa*, *Strychnos nux-vomica*, *Morinda tiuactoria*, *Walsura ternata* and *Ochna squarrosa* are the

common associates. *Euphorbia nerifolia* and *Annona squamosa* are seen around the margin of thickets. *Opuntia* spp. replace the indigenous *Euphorbia* in this situation.

Glycosmis flourishes under *Ficus* spp. as the dominant shrub, followed by *Canthium parviflorum*, *Capparis brevispina* and *Xeromphis malabarica*, and in turn, by *Ziziphus oenoplea* and *Prema latifolia*.

Lianas and woody creepers, such as *Aganosma caryophyllata*, *Combretum extensum*, *Dalbergia monosqora* and *Gymnema ceylanica*, *Derris scandens* and *Acacia intzia* are the more conspicuous elements.

Selaginella tenera, *Hemionites arifolia*, *Cheilanthes tenuifolia* and *Adiantum incisum* are the only species of Pteridophytes found in this *Ficetum*.

Vegetation of rocks and stony areas

In the midst of these thickets and *Ficetum* are many stony areas 45 to 90 m in circumference, harbouring larger xerophytes, such as *Euphorbia antoquorum* and *Opuntia* spp. *Caralluma ascendens* is seen as little bushy clumps, with upright leafless stems in the most exposed situations.

Phanerogamic flora of the Chilka lagoon

In the vast expanse of the brackish water of the Chilka lagoon lie submerged only one major species of angiosperm, viz. *Potamogeton pectinatus* L. mixed with *Najas faveolatas* A. Br. ex Magam. and *N.graminea* Del., *Ruppia rostellata* Koch, *Halophila ovalis* Hook. f and *H. balfouri* Solered., either as submerged or floating elements. *P. pectinatus* and *Najas* spp. form the most dominant weeds and now cover large tracts and pose serious threats to the very survival of Chilka lagoon as the largest brackish watermass of India. Both the Government of India and Government of Orissa are now seriously concerned in the control and eradication of these weeds to prevent conversion of the lagoon to a fresh water swamp in the foreseeable future.

Appendix 1 attached, lists about 150 species of vascular plants reported/collected from the Chilka lagoon and its islands and surroundings. While the names of plants are based largely on Narayanswami and Carter (1920), there is an effort to up-date the nomenclature of names of plants. Critical notes on the habit and phenology and the localities of occurrence are also provided.

Appendix 1

List of 150 species of vascular plants collected/reported from the Chilka lagoon, its islands and the shore-line facing the Bay of Bengal.

Annonaceae

1. *Annona squamosa* L. The Custard Apple, *Ata*, Sweet sop, Barkuda. Excellent fruit in September; flowering May onwards. Has naturalized; an inhabitant of tropical America.
2. *Alphonsea sclerocarpa* Thwaites
Barkuda. A common tree in the island.

Menispermaceae

3. *Cissampelos pariera* L. var. *hirsuta* (DC.) Forman,
Barkuda. Creeper on *Opuntia* sp. Flowers in rainy season.
4. *Tinospora cordifolia* Miers.
Barkuda. Creeper on large *Ficus* trees; only one plant seen.

Capparaceae

5. *Capparis brevispina* DC.
Barkuda. A common shrub, the leaves of which are almost always destroyed by insects and deer. Flowers in June; fruit ripens in June.
6. *Capparis roxburghii* DC.
Barkuda. A large creeper with red fruits growing over trees at the edge of the island and occasionally inland. Flowers in October and April.
7. *Capparis sepiaria* L.
Barkuda and Cherriakuda.
Large weedy climber overwhelming *Azadirachta indica* in mixed thickets. Flowers in April.
8. *Crataeva magna* (Lour.) DC.
C. trifoliata Roxb.
Barkuda and outer channel Peninsula. A common tree at the edge of the marginal zone. Flowers in September and in winter months. Petals pale yellow; fruits scarlet when ripe in July.

Caryophyllaceae

9. *Polycarpaea corymbosa* Lam.
Barkuda. Growing up only in dry weather. Scarce.

Portulacaceae

10. *Portulaca quadrifida* L. var. *meridiana* (L.) V. Narayanswami
Barkuda. Growing among stones at the edge of and on the top of walls; also on stones near the shore of the lake. Flowers in June onwards.

Rutaceae

11. *Toddalia asiatica* Lam. var. *gracilis* Gamble.
Barkuda. A climbing shrub.
12. *Glycosmis pentaphylla* (Retz.) DC. [*G. arborea* (Roxb.) DC.]
Barkuda. A common shrub. Flowers at all seasons. The leaves are upto 24 cm long, leaflets serrate and inflorescences to 8 cm long; *G. mauritiana* (Lam.) Tanaka is the smaller species with leaves to 8 cm long, leaflets entire and inflorescences to 8 cm long. (see Nicolson and Suresh, Taxon 34 : 715-716, 1985).
13. *Atlantia monophylla* Correa
Barkuda. Scarce.

Meliaceae

14. *Azadirachta indica* A. Juss
Barkuda. The most abundant tree in the island. Flowers in April and August and fruits ripe in June.
15. *Cipadessa fruticosa* Bl.
Barkuda. A bushy shrub or small tree.
16. *Walsura piscida* Roxb.
Barkuda. A small tree in mixed thickets. Flow. : Oct.; Fruit : April.
- 16a. *W. ternata* Roxb.

Sapindaceae

17. *Allophyllus Cobbe* Bl. var. *glaber* (Hiern) V. Narayanswami.
Barkuda.
18. *Hemigyroza canescens* Thw.
Barkuda. A mango-like tree; flow. : April; fruit : May-June.

Rhamnaceae

19. *Zizyphus oenoplia* Mill.
Barkuda. A thorny climbing shrub, common in mixed thickets. Flow. : August-September.

Vitaceae

20. *Cissus vitiginea* L.
Barkuda.

Growing over tree in jungle : flowers throughout rainy season. Flowers very attractive to butterflies of various kinds.

21. *Cissus quadrangularis* L.

Barkuda.

A very common climber on every kind of tree and shrub, especially on the larger *Ficus*; springs up readily in deep shade on stony ground. In full flower in the beginning of June.

22. *Cayratia carnosa* Gagnep.

Barkuda.

Tiliaceae

23. *Grewia orientalis* L.

Barkuda. In thickets.

Malvaceae

24. *Sida cordifolia* L.

Barkuda. Quite common, but always eaten up by the deer. Flowers at the end of the rains.

- 24a. *Helicteres isora* L.

Barkuda and small islands.

Ochnaceae

25. *Ochna squarrosa* L.

Barkuda. A tree in secondary forests, not abundant. Flowers-April.

Violaceae

26. *Hybanthus enneaspermum* DC.

Barkuda. On edge of well; typical. Flowers in rains.

Anacardiaceae

27. *Lannaea coromandelica* (Houtt.) Merril.

Barkuda. A large tree common in the sandy area on the north side. Flowers in April without leaves.

Hippocratiaceae

28. *Reissantia indica* (Willd.) Halle

(*Hippocratia indica* Willd.)

Barkuda. An overwhelming creeper, very common; Flow. : Sept.-June.

Leguminosae (Fabaceae).

29. *Albizia odoratissima* (L.f.) Benth.

Barkuda. A tree in sandy area in *Cassipourea* thickets. Scarce.

30. *Dichrostachys cinerea* Wight and Arnott.
Barkuda. Small tree, scarce on the island; common on Ghat Sila and Rambha. Proximal part of the inflorescence mauve coloured distal part bright yellow.
31. *Acacia intsia* Willd.
Barkuda. An overwhelmingly prickly climber. Flow. : Sept.; Fruit : Dec.
32. *Crotalaria pallida* Aiton (*C. striata* DC.)
Barkuda. A herbaceous shrub; common in cleared places towards end of rainy season; dies at the end of winter.
33. *Indigofera linifolia* var. *campbelli* (Baker) Ramaya
Barkuda. Scarce.
34. *Tamarindus indica* L.
Barkuda and small islands.
35. *Tephrosia purpurea* (L.) Pers.
Barkuda. Most abundant in places cleared of jungle from June to Sept.
36. *Dalbergia monosperma* Dalz.
Barkuda. An overwhelming creeper with small leaves. Flow. : Mar.-Apr.
37. *Pongamia pinnata* (L.) Pierre
Barkuda. A tree growing in an almost complete ring round the island within high water level; hardly in the interior of the island. Flow. : April (December); Fruit : all seasons.
38. *Derris trifoliolata* Lour. (*D. scandens* Benth.)
Barkuda. A large climbing shrub, with flowers rosy white; Flow. : Rainy season.
39. *Abrus precatorius* L. (Gunja-Oriya)
Barkuda. Scarce.
40. *Canavalia ensiformis* (L.) DC. *The sword-bean*.
Barkuda. Flowers towards the end of rainy season. Seeds eatable.
41. *Canavalia virosa* Wight & Arnott.
Barkuda. A climber. Flowers towards the end of the rainy season. Seeds bitter for man, but forms the food for the caterpillars of *Papilio hector* and *P. aristolochiae* on the sland.

Cactaceae

41. *Cereus* sp.
Barkuda. Columnar cactus, runs wild. Flowers in hot weather and rains.
42. *Opuntia* spp.
Barkuda. Flowers of a curious orange-shaded with pink.
Flowers : April.

43. *Opuntia monacantha* Haw.

Chheriakuda. Flowers bright yellow with outer petals stained with scarlet; spines growing singly are larger and less easily detached.

Barringtoniaceae

44. *Barringtonia acutangula* Gaertn.

Barkuda. A single tree at edge of lake. Flowers-June to October.

Rhizophoraceae

45. *Cassipourea ceylanica* (Gardn.) Alston

Weihea ceyanica (Gardn.) Baill.

Barkuda. Flower. : April, capsules-June.

Combretaceae

46. *C. latifolium* Bl. (*C. extensum* Roxb.)

Barkuda. A very overwhelming climber very common in mixed thickets. Towards the end of rains, it sends out long shoots. Flowers between December to April and seeds ripen in April.

Myrtaceae

47. *Eugenia rothii* Panigr. *E. bracteata* Roxb., non).

Barkuda. A small tree in sandy area. ; flower : April.

Salvadoraceae

48. *Salvadora persica* L.

Barkuda. A small tree growing only among rocks at the edge of the lake. Trunk thick and distorted and twisted. Leaves very bright green. Fruits ripen in April.

49. *Azima tetraantha* Lam.

Barkuda. A spiny creeper growing over *Cassipourea* in sandy area. Scarce.

Rubiaceae

50. *Oldenlandia corymbosa*

Barkuda. Grows at the edge of the pond; very common on other islands.

51. *Oldenlandia herbacea* (L.) Roxb.

Barkuda. abundant and indigenous in the island; on stony ground in shade at the edge of paths and open spaces.

52. *Oldenlandia nudicaulis* Roth

Barkuda. On stony ground in the shade of bushes and in Ficetum.

53. *Peromphis malabarica* (Lam.)

Barkuda. A shrub with white flowers and red berries. Flower : June.

54. *Canthium parviflorum* Lam.

Barkuda. A large shrub or bush in mixed thickets, reduced small shrub in rocky places. Leaves cooked with rice and eaten during famine. The deer also eats it. Very common. Flower : Sept. or more profusely from April to June.

55. *Morinda tomentosa* Heyne ex Roth (*M. tinctoria* Roxb.)

Barkuda. A common large tree in thickets.

Asteraceae

56. *Eclipta prostrata* (L.) L.

Barkuda. At the edge of the pond among stones.

57. *Blumea* sp.

Barkuda. Springing up in December.

58. *Tridax procumbens* L.

Barkuda. On steps leading to the pond—a weak straggling herb.

59. *Vernonia cinerea* Less.

Barkuda. A very variable plant found flowering in all seasons.

Loganiaceae

60. *Strychnos nux-vomica* L.

Barkuda. A fairly common tree in mixed thickets. Flower & Fruit : Apr.

Apocynaceae

61. *Aganosma caryophyllata* (Wall.) G. Den

Barkuda. Flowers throughout the rains; flowers with a very strong and sweet odour; fruits dehisce in April.

Asclepiadaceae

62. *Cryptolepis elegans* Wall.

Barkuda. A common creeper in mixed thickets; flowers pale greenish yellow.

63. *Calotropis gigantea* (L.) Dryand.

Barkuda. *Akand*.

64. *Calotropis acia* Buch.-Ham.

Barkuda. scarce—a solitary plant among rocks on the edge of the lake; much eaten by deer, and grasshoppers.

65. *Sarcostemma acidum* (Roxb.) Voigt (*S. brovistigma* Wight).

Barkuda. A trailing leafless shrub common on prickly pear. Flowering in the rains; also ripe fruits seen then.

66. *Gymnema sylvestre* (Retz.) R. Br. ex Schultes
Barkuda. A large weedy climber. Common.
67. *Leptadenia reticulata* (Retz.) Wight & Arn.
Barkuda. Common creeper with small greenish white flowers. Flowers throughout the rainy season.
68. *Caralluma adscendens* Haworth.
Barkuda. An erect leafless herb in small patches on open stony places. Common.

Convolvulaceae

69. *Ipomoea sepiaria* Koen.
Barkuda. On bushes near the edge of the lake.
Ganta Sila and Rambha.
70. *Ipomoea pescarpae* Roth
Barkuda. Scarce. On sandy foreshore.
71. *Evolvulus alsinoides* (L.) L.
Barkuda. Scarce; on paths in December.
72. *Cressa cretica* L.
Barkuda. A shore plant, growing up only when the shore is exposed.
Flowers in April and dying off at the end of hot weather.

Boraginaceae

73. *Coldenia procumbens* L.
Barkuda. Forming flat mats on sandy pockets in the beach; grows up between December and April and dies off before June.

73a. *Heliotropium curassavium*

Verbenaceae

74. *Phyla nodiflora* (L.) Greene
Barkuda. On the beach in April.
75. *Premna latifolia* Roxb.
Barkuda. A common plant in mixed thickets, often reaching considerable size; two flowering seasons : April and the rains.
76. *Premna lotifolia* var *cuneata* Clarke
Barkuda. Tree, common in sandy areas.
77. *Premna lotifolia* var *viburnoides* Wall.
Barkuda. Plant remains green when dry in contrast to the blue-black colour of the other two varieties. Its flowers have a strong smell.

78. *Premna wightiana* Schauer
Barkuda. A creeper or scandent shrub; flowers with a peculiar smell very attractive to butterflies, especially *Papilo polytes*.
79. *Clerodendrum inerme* (L.) Gaertner.
Barkuda; Ganta Sila. Very common trailer in Ganta Sila.
80. *Symphorema involucreatum* Roxb.
Barkuda. One of the overwhelming creepers; flowers in April.

Solanaceae

81. *Solanum trilobatum* L.
Barkuda. A scandent thorny shrub-scarce in *Glycosmis* thickets.
82. *Lycopersicon lycopersicum* (L.) Karslen (*L. esculentum* Miller)
Barkuda. Cultivated and becoming established in the island.
- 82a. *L. esculentum*
Miller is conserved by the General Committee in Berlin Cong. 1987.
83. *Datura metel* L.
Barkuda. Very common exhibiting considerable variations in the colour of flowers and stamens—deeply tinged with purple.

Scrophulariaceae

84. *Lindernia hirsuta* (Benth.)
Barkuda. In shade of bushes and fig trees.
85. *Lindernia crustacea* (L.) F. V. Mueller
Barkuda. Growing in shade of bushes on stony ground and at edge of pond.
86. *Bonnaya brachiata* Link & Otto
Barkuda. Among rocks at the edge of pond in the rains.

Acanthaceae

87. *Rungia pectinata* (L.) Nees
Barkuda. On dry ground from December to April.
88. *Justicia diffusa* Wild. var. *prestrata* Roxb.
Barkuda. Very variable; at the edge of a well luxuriant vegetation, spreading and rooting at the nodes; eaten by deer and also growing in clumps on bare stony soil. Flowers in all seasons.
- 88a *Acanthus illiaifolius* L. L

Plumbaginaceae

89. *Plumbago zeylanica* L.
Barkuda. Scarce.

Sapotaceae

90. *Mimusops hexandra* Roxb.

6

Barkuda. Growing among rocks at the edge of lake. Scarce.

Euphorbiaceae

91. *Jatropha heterophylla*

Barkuda. Common both in jungle and in the open. A native of Brazil.

92. *Euphorbia nerifolia* L.

Barkuda. A small tree. Flowers in December; fruits-April.

93. *Euphorbia antiquorum* L.

Barkuda. Trees on rocks. Flowering December; fruits-April

93. (a) *Euphorbia thymifolia* L. Barkuda

94. *Excoecaria agallocha* L.

Barkuda. Scarce; in gravel by the edge of the lake amongst neem and *Crataeva*; a mangrove species.

Moraceae

95. *Ficus benghalensis* L.

Barkuda; one of the commonest indigenous species, but now dying out. Figs red when ripe.

96. *F. arnotiana* (Miq.) Miq.

Barkuda. A large tree; figs dull purple when fully ripe.

97. *F. geniculata* Kurz

Barkuda. large trees; scarce.

98. *F. lambertiana* Miq.

Barkuda. Large trees, common, with coriaceous leaves with broad base; often without adventitious roots; figs, when ripe, white flushed with red purple and dotted when young.

99. *F. microcarpa* L. f. (*F. retusa* auct., non L.)

Barkuda. Large trees; common.

100. *F. religiosa* L.

Barkuda. Not common.

101. *F. tinctoria* Forst. f.

Barkuda. Epiphytic on Banyan and other *Ficus* spp. Figs bright yellow when ripe.

102. *F. tinctoria* sps. *parasitica* (Willd.) Corner

Barkuda. Generally large trees with branches growing upright. at least on the upper part. Leaves dark green and glossy, but scabrid; figs bright yellow.

103. *Plecosperrum spinosum* (Willd.) Trecul
Barkuda. A creeper with strong spines; in mixed thickets; climbing on *Azadirachta indica*.

Chenopodiaceae

104. *Suaeda nudiflora* Moq.
105. *S. maritima* Dumort,
106. *Salicornia brachiata* Roxb. } All these grow on brackish alluvium in the creeks of the lagoon.

Amaranthaceae

107. *Aerva lanata* (L.) Juss.
Barkuda; growing on the wall at the edge of a pond; one of the edaphic variations among plants of the island.
108. *Alternanthera sessilis* (L.) R. Br.
Barkuda; in pockets of sandy alluvium on the rocky beach.

Nyctaginaceae

109. *Boerhavia diffusa* L.
Barkuda. Common weed, among stones at the edge of the lake in rains, or on bare stony ground, or trailing over bushes in undergrowths; in all seasons.

Aizoaceae

110. *Mollugo pentaphylla* L.
Barkuda. On the edge of a well; on stony ground in shade or on bare rocky soil, with long tap root.
111. *Mollugo spedula* L.
Barkuda; on damp rocks, on the edge of a pond in rains.
112. *Sesuvium portulacastrum* L.
On brackish alluvium along creeks of the lake; common in field bunds off Gopalpur.

Hydrocharitaceae

113. *Haophila evalis* Hook. f.
114. *H. balfouri* Solered. } Known as sea-grass, floats on the brackish water, associated with *Potamogeton pectinatus* and *Najas* spp.

Potamogetonaceae

115. *Potamogeton pectinatus* L.
The commonest weed, almost a paste now, submerged and rooting in the alluvium substratum or gets detached and floats. Its eradication and control now poses a serious problem.

Ruppiaceae

116. *Ruppia rostellata* Koch
Chilika Lake (of. Mooney, Suppl. B. B. O. : 140, 1950)

Najadaceae

117. *Najas foveolata* A. Br. ex Magam. } Both these species are associated with
118. *N. graminea* Del. } *P. pectinatus* and form mats or get detached
and float about in the watermass.

Liliaceae

119. *Asparagus racemosus* Willd.
Barkuda; growing on *Canthium parviflorum*; scarce.
120. *Gloriosa superba* L.
Barkuda. Scarce. One of the important medicinal plants for family-planning. Rich source of the alkaloid Diosogenin.

Dioscoreaceae

121. *Dioscorea oppositifolia* L.
Barkuda. Common on thickets of *Cassipourea ceylanica*.
122. *D. sativa* L.
Barkuda. climbing on *Glycosmis pontaphylla* thickets.

Commelinaceae

123. *Cyanotis cristata* (L.) Don
Barkuda; in the shade of brick walls or rock walls.

Cyperaceae

124. *Bulbostylis barbata* var *pulchella* Thw.
Barkuda; growing among rocks at the edge of a pond.
125. *Cyperus compressus* L.
Barkuda; growing on the sandy shore near the upper flood level.
126. *Cyperus cuspidatus* Kunth form *angustifolia* Clarke.
Barkuda; growing among rocks or among the herbaceous growth along a footpath.
127. *Fimbristylis dichotoma* Vahl
Barkuda; in the sandy foreshore.
128. *Lipocarpa senegalensis* (Lam.) T. Durand et H. Durand
Barkuda; at the edge of a footpath.
129. *Mariscus albescens* Gaud.
Barkuda; between rocks in water near the edge of a pond; flowers in April and again from July to October.

130. *Mariscus* aff. *Dregeanus* Kunth
Barkuda; rare (The nuts are present in all the spikelets; nuts dorsally compressed and larger than those of *M. Dregeanus*).
131. *Schoenoplectus littoralis* (Schrader) Palla
(*Scirpus littoralis* Schrader).

Poaceae

132. *Aeluropus laevis* Trin. (*A. lagopoides* Trin. ex Thw).
In the brackish alluvium along creeks, associated with *Suaeda* spp. and *Sesuvium portulacastrum*: abundant off Gopalpur.
133. *Bambusa orundinacea* Retz.
Barkuda; common.
134. *Cynodon dactylon* (L.) Pers.
Barkuda and elsewhere; common on alluvial soil.
135. *Eleusine aegyptiaca* Desf.
Barkuda; on loose stony soil.
136. *Eragrostis interrupta* P. Beauv.
Barkuda; scarce; on footpath.
137. *E. tenella* Roem. et Schult. var. *breviculmis* Stapf.
Barkuda; scarce, along footpath.
138. *E. tenella* var. *plumosa* Stapf.
• Barkuda; on the edge of a well or on bare stony ground.
139. *Panicum tripheron* Schult.
Barkuda; on bare stony ground; chiefly in rainy season.
140. *Phragmites karka* Trin
Nalabana; in the swamps; good fodder for buffaloes; almost exhausted.

Pteridophytes

141. *Selaginella tenera* Spring
Barkuda; on soil among stones in the thick jungle; in the rains.
142. *Hemionites arifolia* Burm. f.
Barkuda; on rock cervics at the edge of a pond, or in shade of bushes on stony ground in the interior.
143. *Adiantum incisum* Forsk $\frac{1}{2}$
Barkuda; associated with *H. arifolia* Burm. f.; most plants wither in dry season.

144. *Cheilanthes tenuifolia* Sw.

Barkuda, on the wall at the edge of a pond or in rock cervices; scarce.

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A Contribution to the Flora and Vegetation of Chilika Wild Life Sanctuary, Orissa

P. C. Panda* and S. N. Patnaik**

The paper presents an account of the flora and vegetation of Chilika lagoon in the State of Orissa. Out of the total of 352 species of plants collected during the survey *Macrotyloma ciliatum* and *Heliotropium curassavicum* are reported as new distributional records. Notes on some rare plants and their conservation, environmental impacts on the ecosystem and possible means of eco-development etc., have also been discussed.

Introduction

Chilika, the biggest brackish water lagoon of India, is situated in the coast of Orissa at the border of Puri and Ganjam districts between 19° 18'—19° 54'N latitudes and 85° 6'—85° 35'E longitudes. It was declared as protected forest and sanctuary under the Shooting Rules, 1972 (Vide F.F. and A.H. Department, Govt. of Orissa, Notification No. 10 F(W)/73-16094-F.F.-AH., dated 15.10.1983). The lagoon is rich with varied species.

Botanical work : past and present

Although the algal flora of the lake has been studied in detail (Biswas, 1924 & 1932), there are a few sporadic accounts on the vascular plants of this region. Haines (1921-25), Mooney (1950), Patnaik (1973), Panda & Patnaik (1985) and Paul *et al.*, (1983) have made significant contributions to the floristics of this region. However, these reports are very fragmentary in nature and no exhaustive survey report is yet available to assess the potentiality of plant resources of this unique habitat.

Realising the meagreness of floristic accounts, changing pattern of vegetational composition and in view of the present importance laid on Chilika as a valuable wildlife habitat, a detailed survey was carried out by the authors during 1983-86. Under the programme, 352 angiospermic species of plants belonging to 272 genera under 96 families have been collected, identified and preserved in the Herbarium of the Department of Botany, Utkal University, Bhubaneswar. Of these, *Macrotyloma ciliatum* and *Heliotropium curassavicum* turned out to be new distributional records for Eastern India (Panda *et al.* 1986) and Orissa respectively.

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Synoptic analysis of vegetation

Depending upon the local habitat condition, the vegetation of Chilika lake and its adjoining regions come under the following three broad categories :

a) Aquatic vegetation :

The depth of water, salinity and nature of substratum are, to a large extent, responsible for the distribution and abundance of aquatic plant communities in the lake water. The aquatic vegetation is characterised by a few species of brackish-water submerged phanerogams like *Potamogeton pectinatus*, *Halophila ovalis*, *Ruppia maritima*, *Najas faveolata*, *Hydrilla verticillata* and *Ceratophyllum demersum*. Of these, the first two are widely distributed and are of quantitative importance. *Potamogeton pectinatus*, being the most dominant element, grows well at any depth of water and withstands wide range of salt concentrations but *Halophila ovalis* prefers sandy substratum with comparatively less fluctuations in salinity. Though not collected during the present study, the occurrence of *Potamogeton octandrus*, *Najas graminea* and *Halophila beccarii* has been reported by earlier workers (Haines, 1921-25, Mooney 1950 and Patnaik 1973).

Some floating plants such as *Eichhornia crassipes*, *Pistia stratiotes* and *Azolla pinnata* which enter the lake in large colonies with flood water remain in patches for some-time but subsequently die out and disappear, probably being unable to withstand the rise in salinity. In addition, the shallow and muddy margins are inhabited by large communities of *Schoenoplectus littoralis* in association with *Eleocharis dulce*, *Phragmites karka*, *Myrostachya wightii* and many other grasses and sedges.

b) Littoral scrub jungles :

The mangroves which were once plentiful towards the margin of the lake and its uninhabited islands like Badakuda, Sanakuda, Cherikuda, and Ghantasila etc., are no more found due to ruthless cutting and destruction in the past by the natives for various purposes. The only vegetation now extant are the littoral scrub jungles along the rocky faces, representing the remnants of one time dominant tidal swamp forests. These are resultant of dry conditions due to poor soil combined with strong sea wind and biotic interference of several categories and magnitudes. The vegetation is completely devoid of arboreous species of mangroves though some of their associates like *Salvadora persica*, *Pongamia pinnata*, *Cassipourea ceylanica* etc., could only be observed in denuded condition giving the appearance of low shrubs. Other important species constituting this type of vegetation are *Aegiceras corniculatum*, *Azima tetracantha*, *Colubrina asiatica*, *Clerodendron inerme*, *Pisonia aculeata*, *Carmona retusa*, *Meytinus emarginatus*, *Carissa spinarum*, *Opuntia dillenii* etc. Climbers/twiners are fairly common in such degraded scrub jungles, of which *Cissus quadrangularis*, *Pentatropis capensis*, *Capparis roxburghii*, *C. zeylanica*, *Tylophora indica*, *Sarcostemma acidum*, *Derris trifoliata*

and *Maerua oblongifolia* are quite abundant. Tree species either belonging to mangroves or their associates are very rare and non-mangrove trees are represented by *Ficus* spp., *Crateva adansonii* spp., *Lepisanthes tetraphylla* and *Streblus asper*.

The ground flora is composed of a large number of herbaceous members at places where there is considerable accumulation of soil. *Cressa cretica*, *Indigofera aspalathoides*, *Synostemon bacciforme*, *Stylosanthes fruticosa*, *Trianthema triquetra*, *Heliotropium curassavicum* form the vegetation in such habitats. *Solanum trilobatum* is fairly common among bushes and scrub jungles. The steep rocks at certain places are covered with almost matted growth of *Dalbergia rubiginosa*. Exotic shrubs like *Chromolaena odorata*, *Lantana camara* var. *aculeata*, *Jatropha gossypifolia* etc., have invaded the vegetation of most of the rocky islands and adversely affected the indigenous flora.

Suaeda maritima, *Salicornia brachiata*, *Sesuvium portulacastrum*, *Phyla nodiflora*, *Heliotropium curassavicum*, *Diplachne fusca* and some others are quite gregarious in marshes and salt fields along the edges of the lake.

c) Sand-dunes and psammophytic vegetation :

The scorching sun, shifting sands and salt laden wind on the beaches near the lake support an interesting psammophytic vegetation. *Hydrophyllax maritima*, *Ipomoea pescaprae*, *Macrotyloma ciliatum*, *Launea sarmentosa* are the common broad leaved runners on the dunes. Other dominant herbaceous elements constitute *Cyperus arenarius*, *Spinifex littoreus*, *Bulbostylis barbata*, *Geniosporum tenuiflorum*, *Hedyotis graminifolia* ssp. *arenaria*, *Brachiaria remota*, *Acalypha lanceolata*, *Bacopa monnieri*, *Vigna sublobata*, *Crotalaria nana*, *Gisekia pharnaceoides* etc. *Zoysia matrella* is very frequent in marshy localities. *Pandanus fascicularis* attains very large dimension due to congenial edaphic factor and is found in almost a continuous belt along the fringes of the lake. The common associates are *Euphorbia tirucalli*, *Pentatropis capensis*, *Asystasia gangetica*, *Ipomoea obscura* and *Tinospora cordifolia*. Shrubs like *Abutilon hirtum* and *Abelmoschus ficulneus* also occur in profusion. A stretch of land lying in between Bay of Bengal and Chilika lake has been planted with *Casuarina equisetifolia* which exhibit luxuriant growth and adequate natural regeneration.

Some ecological considerations and suggestions

While comparing the list of species reported by previous workers and those occurring today, it could be realised that there have been considerable changes in the pattern of vegetation and its species composition along the year. In spite of all the changes, even today, it harbours a large number of rare plants due to specific habitat conditions. *Cassipourea ceylanica*, *Colubrina asiatica*, *Salicornia brachiata*, *Indigofera aspalathoides*, *Maerua oblongifolia* and *Macrotyloma ciliatum* are some of the taxa deserving special attention for study and conservation. Further, the existing vegetation is prone to human interferences of various kinds and magnitudes connected with clear felling of natural

vegetation, introduction of exotic species, expansion of agricultural land, pisciculture, navigation, tourism, naval exercises, etc. Some developmental projects, architectural complexes and industries have already been established in the neighbourhood⁶ and many others are likely to come up in future. All these are bound to have some impact on the quality of the environment. The mouth of the lake at "Magarmukh" is getting narrower resulting in less inflow of sea water and the lake bed is rising upgradually with the deposition of silt brought down by the river. This has a serious impact on the aquatic life-forms and on the overall ecosystem. The population of fishes, crabs, dolphins, water-snakes in the lake water and the black-bucks, deers, feral-cattle of the islands have gone down. The arrival of migratory birds has receded during the last few years.

Evidently, therefore, conservation of this habitat alongwith its various life-forms on an ecologically sustainable manner is the need of the day. The following few suggestions may be of some value in achieving the objectives.

1. Ecologically more vulnerable spots should be identified and human activities in these areas must be strictly regulated as far as practicable.
2. Shooting and trapping of birds and poaching of wild animals must be strictly forbidden and fishing should be confined to demarcated zones.
3. The training activities and naval exercises of the Naval Training Centre should be confined to a limited area.
4. The mouth of the rivers connecting Chilika lake and the lake mouth at Magarmukh should be reclaimed from sand and silt.
5. The barren rocks and islands must be planted with suitable indigenous multipurpose tree species to check excessive soil erosion and provide shelter and breeding ground for birds.
6. Adequate protection should be given to degraded littoral forests for natural regeneration and establishment. Some islands like Badakuda and Sanakuda containing a good population of *Pongamia pinnata* and *Cassipourea ceylanica* must be left for natural growth and regeneration. While the former is a fast-growing tree, latter is a threatened species in Indian flora.
7. For the eco-development of the area, a coordinated research project on the study of flora, fauna, soil, geology, water quality, fishery must be initiated.

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Fauna of the Chilika Lagoon—A Status Appraisal

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The fauna of the Chilika lagoon was studied extensively during 1915-1924 by the Zoological Survey of India. After this study very little work on the faunal aspects were carried out except a few on the crustaceans and fishes. The available information on the fauna of different groups of the Chilika lagoon is dealt group wise below.

1. PROTOZOA : Annandale (1915) mentioned the presence of several fixed and free protozoa on a submerged timber in Chilika lagoon along with a coelenterate. Annandale & Kemp (1915) reported *Trichodina* from the external surface of Ctenophores. Chilton (1921) observed vorticellid protozoa on a weed from Chilika lagoon.

2. PORIFERA : Annandale (1915) reported 7 species of sponges of which 2 are of freshwater and the remaining of marine waters. Sewell and Annandale (1922) reported 3 species of sponges from Rambha bay.

3. COELENTERATA : 9 specie of Hydrozoa, 1 species of Scyphozoa and 6 species of Anthozoa were reported by Annandale (1915). Hamid (1931) reported *Virgularia gracillima* (Kolliker). Matthai (1924) reported a subfossil Coral from the lagoon. Carlgren (1925) reported on the status of Actiniaria of Chilika lagoon.

4. CTENOPHORA, POLYZOA, ECHIURA, SIPUNCULA, BRACHIOPODA & CHAETOGNATHA :

Annandale and Kemp (1915) reported a single species of Ctenophora and Echiura. Halder (1985) reported 2 species of Echiuroids. Annandale (1915) recorded 2 species of Bryozoa (Ectoprocta) and 1 species of Entoprocta. Sewell and Annandale (1922) reported on the polyzoa occurring in Rambha bay. Devasundaram & Roy (1954) recorded *Sagitta* sp. from Chilika.

5. PLATYHELMINTHES : Tripathy (1956, 1959 & 1977) reported a good account on the monogenean trematodes of the lagoon. Chatterjee (1958) Gupta & Ahmed (1976) & Hafezullah (1984) contributed information on the digenetic trematodes of the fishes of the lagoon. Southwell (1915, 1921 & 1922 a.b) reported on the Cestodes occurring in the birds and fishes of the lagoon.

6. ANNÉLIDA : Southern (1921) reported 20 species of Polychaetes of which 19 were new species. Fauvel (1932, 1953) reported 23 species of Polychaetes from the lagoon.

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A detailed account on the littoral Oligochaeta of the lagoon was studied by Stephenson (1914). Stephenson (1915, 1917) described 4 species of Oligochaetes from the lagoon.

Harding (1920) reported three species of leeches from the lagoon. Kaburaki (1921) recorded five species of leeches from the lagoon.

7. CRUSTACEA : Annandale (1915) reported on Cirripedia while Chilton (1916, 1924) dealt on Isopoda of the lagoon. Kemp (1915, a. b 1916) extensively studied the Stomatopoda, Decapoda and Cumacean fauna. Henderson (1915) recorded hermit crabs from the lagoon. Copepoda was dealt by Sewell (1919, 1924). Tattersall (1915) reported on the fauna of Mysidaceae. Sewell and Annandale (1922) reported on the Crustacean fauna of the Rambha bay. Subramanyam (1966) reported some prawns as new records from the lagoon.

8. INSECTA : Annandale & Kemp (1915) reported on the aquatic insect fauna other than Coleoptera. Laidlaw (1915) gave an account on the Odonata of the lagoon. Annandale & Dover (1921 a, b) reported on the Cicindelid beetles and butterflies. Andrewes (1921) gave an account on the Carabid beetles of the Barkuda island. Dover (1921 a,b,c) reported on the fauna of moths, wasps and bees, dipteran insects and neuropterid insects of the Barkuda island. Fraser and Dover (1922) recorded 30 species of dragonflies and damselflies from the Barkuda island of the Chilika lagoon. Sewell and Annandale (1922) reported on the insect fauna of the Rambha bay. Blair (1922) reported on the Heteromera of Barkuda island. Dover (1922) reported on the free living Thysanura of Barkuda island. Arrow (1923) reported on certain Coleptera of Barkuda island. Silvestri (1923) reported termites of Barkuda island and Annandale (1923) reported on their habits.

9. ARACHNIDA : Gravely (1921) described the spider and scorpion fauna of the Barkuda island.

10. MOLLUSCA : Preston (1914 & 1915) gave an extensive account on the molluscan fauna of the Chilika lagoon. Annandale & Kemp (1916) reported on the Gastropoda and Lamellibranchiata of the lagoon. Eliot (1916) reported on the Nudibranchiata. Sewell and Annandale (1922) reported 20 species of molluscs from the Rambha bay. Hornell (1917) gave a revisionary account on the genus *MERETRIX* from the lagoon. Godwin-Austen (1917) reported on the mollusca collected from the Barkuda island. Annandale (1921) reported on the mollusca collected from the Gopakuda island of the Chilika lagoon. Annandale (1924) gave a further account on the Gastropoda of the Chilika lagoon. Prashad (1939) reported 2 species molluscs.

11. FISHES : Chaudhuri (1916, a, b, c 1917 & 1923) reported on the fish fauna of the Chilika lagoon. Hora (1923) reported on the fish fauna of the lagoon. They recorded 118 species from the lagoon. Koumans (1941) reported 1 species of gobiid from the lagoon.

Mitra (1946) recorded 7 species of fishes of commercial importance. Jones & Sujansinghani (1954) gave a list of fishes of which 25 were reported as new records from the lagoon. Roy and Sahoo (1957) recorded 14 species as new additions to the fish fauna of the lagoon. Menon (1961) listed 72 species of fishes, of which 17 species were new records. Devasundaram (1954) listed 68 species of fishes of which 40 species were found to be commonly occurring forms. Rajan, Patnaik & Basu (1968) recorded 47 additional species of fishes new to the Chilika lagoon.

12. AMPHIBIA & REPTILIA : Annandale (1907) reported the occurrence of 7 species of reptiles and a single species of amphibian from Gopakuda island in the lagoon. Annandale (1915) recorded a single species of frog, 3 species of snakes, 2 species of crocodiles and 3 species of turtles from the Chilika lagoon. Annandale (1917) reported on a new limbless skink from the Barkuda island. Annandale (1921) recorded 2 species of amphibians and 18 species of reptiles from the Barkuda island.

13. BIRDS : An account of 53 species of birds observed on the Barkuda island was reported by Annandale (1921). Recently Hussain, Mahapatra & Sahid Ali (1984) reported on the avifauna of the Chilika lagoon and listed 150 species of birds.

14. MAMMALS : Annandale (1915) recorded 2 species of mammals (an Otter & a cetacean) from the Chilika lagoon. Again Annandale (1921) reported a species of insectivora of the genus *Pachyura*, a rodent *Rattus rattus* and the common bat, the Indian Rying fox. Hinton & Lindsay (1926) gave an account on 9 species of mammals collected from Chilika lagoon by H.W. Wells.

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Avifauna of Chilka Lake

K. K. Mohapatra and S. A. Hussain*

This paper attempts to describe the bird fauna of Chilka lake which is the largest brackish water lake of India. Altogether 150 species of birds have been recorded from the lake area so far. Notes relating chiefly on the status of most common winter visitors are presented. Dowitcher, one of the least known Asian Shorebird and the spoonbill Sandpiper, one of the rarest stints are some of the interesting bird fauna of the lake. Detailed information is also given on the migration pattern of some selected waders and waterfowl. Future research priorities and management options for the Chilka Bird Sanctuary are appraised.

Chilka lake in Orissa is one of the major and important wetland areas in the eastcoast of the Indian peninsula. It serves as one of the most important wintering grounds for the resident as well as migratory birds visiting the lake. While the hydrological, limnological and other aspects of the lake has been studied in detail by several workers (Banerjee and Roychoudhury 1971, Jhingran 1963, Patnaik 1971, Rajan 1971) very scanty information is available on the avifaunal resources of Chilka. No indepth study has been conducted by any individual on the bird life of Chilka lake. However, occasional sight records of migratory waterfowls and waders to Chilka areas has been reported in the Journal of the Bombay Natural History Society (BNHS) from time to time by Tilden (1921), Fooks (1939), Benthall and Craven (1949) and others till the Bombay Natural History Society's Migration Project launched an exploratory survey in Dec. 1965 (Lavkumar 1966). This pilot survey was mainly aimed at to explore the possibilities of ringing the migratory waterfowl. Subsequently the BNHS team ringed a few hundred birds in January 1967. In the first half of eighties the Avifauna Project of the BNHS again initiated studies in Chilka to obtain a first hand knowledge on the bird fauna of this vast lake. These studies were aimed at assessing the winter migration strategy of a large number of waterbirds visiting the lake by trapping and ringing.

Considering the vastness of Chilka and the limited time of survey the information obtained is not adequate. This paper attempts a cursory analysis of the initial data gathered over two brief periods during 1981 and 1984.

The lake which is actually a brackish water inland waterbody, regularly subjected to tidal inflow from the sea as well as run-off from the river, and rainwater from the hinterland. With an area of approximately 1100 sq. km. it is the largest brackish water lake in India, connected with the Bay of Bengal through a channel of 29 km. long and 365 meters

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wide (Fig. 1). Annandale and Kemp (1915) recored the area of the lake' as about 906.5 sq km. (350 sq mile) as early as 1914. whereas Patnaik (1971) gives the figure as 1040 sq km. The variation in area can probably be attributed to the shift in the lake site during monsoon floods. The precise geographical situation of the lake is between latitudes 19° 21' and 19° 54'N and longitudes 85° 6' and 85° 35'E.

The lake hosts over 150 species of birds in the peak migratory season (Hussain *et al* 1984). Of these 32% are aquatic, 22% waders and about 46% are terrestrial birds. The last includes 14 species of birds of prey. Major concentration occurs from about early October upto mid March when bulk of the winter waterfowls arrive and spread out all along the lake.

Due to vastness of the lake it is extremely difficult to assess the number of birds that are either on passage or are wintering in the area. Constant shifting of feeding grounds along the lake make it extremely difficult to guage the species composition and relative abundance of the individual species. While large flocks of birds scatter throughout the lake the major concentration in terms of species abundance is on a small island called 'Nalbana' having an area of approximately 10 sq km. (Nalbana =weed covered marsh in Oriya) is a shallow marshy island which remains completely waterlogged during the major portion of the winter season and thereafter dries up in stages, providing feeding conditions for different species of birds. Thus, while in the beginning of the migration season longlegged as well as dabbling species are abundant small wading species congregate as the island dries up. Between December and February large number of ducks, fish eating birds as well as smaller waders flock in this area to feed or roost. Most of the birds leave the lake in the peak of summer and except for a few passerine and some residential shore birds the lake is devoid of any avifauna.

Perhaps the most interesting feature of the lake's bird population has been its migratory character. Less than one quarter of the recorded species are truly resident, the remaining being seasonal visitors. There are roughly two bird seasons. The hot dry seasons (April to September) when the number of species drops to its yearly low : the fall season (Oct-March) when lake is visited by many migratory species from the palaearctic region beyond Himalayas in Central and Northern Asia. The most regular and abundant winter migrants to this lake are the ducks and geese (Anatidae) and wading birds or shore birds (Charadriidae).

A quick scan of the data obtained over two winter seasons reveal that dabbling ducks (*Anas penelope*, *Anas strepera*, *A. clypeata* and *A. querquedula*) were more or less confined to shallow water areas where as the diving ducks (*Aythya nyroca*, *A. ferina* and *A. fuligula*) spread out in comparatively deeper areas and as such their number may actually be more than other species of ducks. The other diving species, Coot (*Fulica atra*) is also quite abundantly seen in the area adjacent to Naval base.

The probable reason being the greater depth of water which facilitates the birds mobility and the disturbance is almost negligible.

In terms of sheer abundance the Brahminy duck (*Tadorna ferruginea*) occupies the first position. They can be seen all around the Nalbana in compact gregarious flocks. Almost forty years ago Benthall (1949) sighted as many as 15,000 Brahminy duck on the Nalbana island on one occasion. Similarly Fooks (1939) saw abnormal number of Shelduck (*Tadorna tadorna*) in one of his trips to Chilka in 1939. Besides Brahminy duck, Benthall mentions the occurrence of Barheaded Goose, (*Anser indicus*.) Greylag Goose (*Anser anser*) White-fronted Goose (*Anser albifrons*) in addition to Gadwall (*Anas strepera*) Pintail (*A. acuta*), Shoveller (*A. clypeata*), Wigeon (*A. penelope*), common (*A. crecca*), Garganey Teal (*A. querquedula*), Spottailed Duck (*A. poecilorhyncha*), Red Crested Pochard (*Netta rufina*), Tufted Pochard (*Aythya fuligula*) and Common Pochard (*A. ferina*). But he did not come across Nukka or Comb duck (*Sarkidiornis melanotos*), Cotton Teal (*Nettapus coromandelianus*) and Mallard (*Anas platyrhynchos*). Cotton Teal and Mallard do not figure in our sight record of 1981 and 1984 seasons too, thereby indicating that they rarely touch Chilka. There is no record of Large Whistling Teal (*Dendrocygna bicolor*) in Chilka although Lesser Whistling Teal (*Dendrocygna javanica*) are reported often.

Both longlegged and smaller waders congregate in large numbers on the island. Greater and Lesser Flamingos, Grey and Purple Herons, Egrets, Spoonbills, Painted Stork and White Ibis constitute the majority of longlegged waders. Pond Herons and Night Herons become abundant as the water dries up. Long distant migrants constitute the majority of shortlegged waders. Of these the most noteworthy records has been the Spoonbilled Sandpiper (*Eurynorhynchus pygæmus*) and Dowitcher or Snipebilled Godwit (*Limnodromus semipalmatus*) one of the least known Asian shorebird.

The former is a very rare winter migrant (Ali and Ripley 1983). Only four specimens appear to have been recorded within our limit during the last 50 years or so, out of which one was caught in Nalbana of Chilka on the eastern seaboard in 1981 and rest three in the point Calimere Sanctuary of Tamil Nadu—the southernmost tip of the Indian peninsula. This tiny wader weighing hardly 20-22 gms migrants all the way from Siberia for wintering in India. The Snipebilled Godwit or the Asian Dowitcher as it is commonly called is a rare vagrant (Ali and Ripley 1983). It has been obtained at long intervals since first described in 1948. Periodical references has been made on the occurrence of this species in Chilka by Fooks (1939) and Ali & Ripley (1983). In 1984 twelve individuals of this species were caught and ringed in Chilka. This is the third authentic record of the species.

Brownheaded and Blackheaded constitute the majority of gulls. Seven species of terns were recorded from Chilka area of which Little tern (*Sterna albifrons*) breeds on Nalbana island.

Fourteen species of birds of prey were recorded, of these six species were observed over Nalbana island. Pariah Kite (*Milvus migrans*) appears to be the most common.

Large concentration of prey species in this area appears to attract them to the island. Most of the Passerine as well as non-passerines can be encountered either on the Nalbana Island or on the shore of the lake. Nalbana when dries up towards the latter half of March provides excellent nesting site for five species of birds. They are Little Tern *Sterna albifrons*, Gulbilled Tern (*Gelochelidon nilotica*), Blackwinged Stilt (*Himantopus himantopus*), Eastern Sky Lark (*Alauda gulgula*) and Small Indian Partincole (*Glareola pratincola*). It is possible that a few other resident birds may also do breeding here.

The most interesting finding of our studies relates to migration strategy of the wintering birds to Chilika. Where as from amongst 5000 birds ringed in Chilka in different years starting from 1967, 25 individuals have been recovered mostly from Central and Northern Asia thereby indicating the migrational route they select (Fig.-1 and Table-1) On the contrary a single record of a Stint (*Calidris minuta*) which was ringed by the Bird Ringing Centre, Moscow, at Alma Ata, Sorbulak lake, Kazakhstan U.S.S.R. was recovered in Chilka in 1984. Another interesting recovery is that of a Curlew Sand Piper (*Calidrus testacea*) which was ringed at Point Calimere Bird Sanctuary of Tamil Nadu and was caught in Chilka in March 1981 while on its return Journey to Siberia. One more interesting recovery is from China too. The bird, a Curlew Sandpiper (*Calidris testacea*) was ringed at Chiika on 28.3.1981 and was captured at Tianjing, China on 15.5 1985 after a gap of 4 years and 2 months. All migratory birds perform long and hazardous journey involving thousands of kilometers. One probable route is the trans-Himalayan route through the mountain passes whereas the other is through Pakistan, Afganisthan, finally leading to Central Asia.

Among the wetlands of India, Chilika occupies a place of pride as this is the only lake of Orissa and second only in the whole of the country to be declared as a wetland of international importance under the Ramsar Convention, 1974. Further Chilka lake was declared as a bird sanctuary since 1973. Inspite of this, uncontrolled shooting, netting and snaring of birds is carried on by local people as well as fishermen around Nalbana and elsewhere in the lake. Another major cause for disturbance to wintering birds in Chilka in general and Nalbana in particular is the presence of a large number of fishing vessels. Therefore, a careful assessment will have to be made to evolve an effective management policy to conserve the bird fauna of lake. However, we strongly feel that a continuous monitoring of the area is essential to obtain precise data on the winter migration strategy of certain avian species visiting Chilka lake. From our own experience from the last two field camps we feel that the bird fauna of the lake is in a state of flux. Thereiore, a longterm study is necessary to study the fluctuations in the bird fauna of Chilka and their relation to Chilka environment.

In a report submitted to the Orissa Government the Society recommended*the following measures for the conservation of Chilka lake (Hussain *et al.* 1984)

Table-1

Chilka Bird Sanctuary-Recovery Data

Species	Sex	Date ringed	Date and place where recovered	Time Lapse	App. distance kms.
Tadorna ferruginea G—2914	M	2.3.1981	0.3.1983, Padma river Kushtia dist. Bangal Desh 23.55N; 89.10E	Approx 2 years	640
Anas crecca C—39261	M	11.2.1981	5.6.1981, Yakut ASSR Zhigansky dist. 66.50N; 123.30E.	114 days (3 months 24 days)	6080
Anas penelope F—39726	M	4.3.1981	5.6.1982, Yakut ASSR Zhigansky dist. 66.50N; 123.30E.	458 days (1 year 3 months, 3 days)	6080
Anas penelope F—39752	F	5.3.1981	3.9.1981, Yakut ASSR Kabyayaki dist. 63.54N; 127.20E.	187 days (6 months 2 days)	6080
Anas clypeata F—39647	F	27.2.1981	(15-22).5.1982 Yakut ASSR Viluysky dist. 63.39N; 121.32E.	—	6800
Anas clypeata F—39602	M	24.2.1981	18.5.1982, Yakut ASSR Viluyski dist. 63.39N; 121.32E.	448 days (1 year 2 months, 23 days)	5800
Tringa nebularia		17.3.1981	24.5.1983, Sverdlovsk O Varkhoturskiy reg. ASSR 58.48N; 60.31E.	798 days (2 years 2 months, 8 days)	5000
Calidris testaceus AD—95048	*	25.11.1980	5.3.1981, Chilka Lake	100 days (3 months 10 days)	1200

* Ringed in our field station at Point Calimere, Thanjavur dist. Tamil Nadu.

1. Declare the entire lake as a sanctuary but effective control must be exercised in and around Nalbana island which should be declared as a core area.
2. All fishing, grazing and activities other than research should be banned in the area. Three kms. radius around the Nalbana should be considered out of bounds for fishing during winter months.
3. Fishing can be allowed in the areas other than the core area only.
4. Night fishing should be banned. This creates maximum disturbance to the roosting birds.
5. Bring the entire lake under the jurisdiction of the wildlife department for effective control.
6. Increase the wildlife staff. The Chilka staff should preferably be headed by an officer of DFO rank, who should be assisted by at least two range officers to look after the entire lake.
7. The wildlife wing must have at least one motor launch and several small fibreglass boats with out board motors, apart from sailboats.
8. If bird watching trips are to be conducted for tourists and others it should be done around the island in sailboats only.
9. Field research such as bird ringing, census and other ecological studies should be carried out regularly.

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Environmental Survey of Chilka

*N. K. Das & R. C. Samal

Introduction

Queen of lakes, vast and picturesque, Chilka, has a pride of place among the internationally acknowledged wetland habitats. Wealth of it lies in the bird sanctuary of Nalabana, which hosts the visitors from the far north. It has been the source of sustenance for scores of thousands of fishermen folk around. It has lived a legend of naval tradesman voyaging out to near east.

All the glory that paints a rich heritage point do fade away with march of time, human interference and neglect; Chilka is no exception. Formidable problems of environmental degradation and ecological imbalances have assumed a grave posture, the challenge of which has to be met with resolute action.

A large number of studies have been conducted by researchers and governmental agencies in the past adducing valuable data. It has however been short of comprehension for environmental conservation and development planning. The survey has therefore been taken up by ORSAC in association with others since September '87. Remote Sensing being the most appropriate technology for rapid & synoptic studies, the studies were largely based on the same, with however liberal use of historical end ground monitoring data. A Synthetic Aperture Radar Survey of the area has also been undertaken using a Canadian facility contracted through the Department of Space. Study of ocean parameters of Chilka was also simultaneously conducted from the research vessel 'Gavesini' of NIO.

Scientist of ZSI, NIO, Marine Science Department of Berhampur University, Directorate of Fisheries, Orissa and other organisations have also cooperated in the surveys. The data analysis and interpretation is in progress. The salient findings only are embodied in this note.

Lagoonal characters

The wetland system includes the lake proper, the swamps occurring along the coast from Chilka mouth near Arakhakuda upto Puri and further inland upto Brahmagiri. There are a number of abandoned channels in the northern periphery area which are in hydrologic communication with the swamps and the lake. A number of beach ridges are seen occurring

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in the area north-east of lake indicating coastline changes. The lake receives a number of direct discharging streams all along its western margin which together with overland flow contribute to sedimentation along the western margin and the entire watershed of these streams is characterised by steep sloping hills and narrow moderately sloping pediment. The lake is also fed by branches of Mahanadi, chiefly Daya-Bhargavi which in addition to the sediment carried by the river from upstream areas also collect loose sediment from deltaic alluvial deposits within which the sinuous streams flow.

The lake is strongly influenced by the above watershed and for a proper environmental management and an area over 4300 sq. kms. need to be covered under effective conservation measures.

The sedimentation is occurring throughout the lake. Almost the entire north-eastern part of the lake is less than 1.5 meters deep and the bed slope is towards southwest. The deeper water in Kalijai area has a depth of 2-3 meters. The channel communicating the sea is shallow varying from 1 to 1.5 meters in most part. The bathymetric map reflects present bed topography which is presumed to be strongly influenced by the inherited structure of the Easternghat rocks particularly the cross folds. The coastal inlands occurring to the west of the spit are entangled in a web of channel complex. One channel, west of Krushnaprasad and east of Tichhini are almost shut off from the lake. The only communicating channel west of Nuapada runs for 25 kms. to its mouth near Arakhakuda. One branch of this channel however has a small but direct communication to the lake across Tua-Gomhari promontory which needs close study for possible artificial reopening.

The lake had in the past more than one opening to the sea. In 1980 it was described as one mile wide and fairly deep. In 1825 the mouth had been reportedly artificially cut. In 1907 it was 200' wide and intermittently artificially opened. In 1930, Survey of India mapped three mouths near Arakhakud. In 1938 single mouth was almost choked and during ebb tide one could walk across. In 1965 the mouth was 8 kms. northeast of Arakhakud having 1931 meters width. In 1968 it was reduced to 400 meters. Now, at present, it is 300 meters wide, being situated near Arkhakuda.

There are three main types of weeds i.e. Benthic, Submerged and Emergent. The most wide spread types are Potamogeton, Heliophyta and Najas. The Algal types are Gracilaria, Spirogyra, Enteromorpha, Cheatomorph and Lyngbya. The Phytoplanktons are chiefly diatoms and zooplanktons are copepods.

The fish resources of the lake are predominantly prawn (32%) mullets (29%) with highest landing of 5400 tonnes per year. Salinity varies with season and area. In March-June period mouth area shows highest salinity of 23-29 PPT. During this period, the southern area around Rambha shows 15 PPT while the water around Satpada varies from 16-25 PPT. It is however reduced (8 to 11 PPT) in Kalupadaghat area. In July-October period the salinity is somewhat similar but during November-February period it reduces considerably in all areas except the mouth. The surface temperature varies from 23-33°.

extreme annual average reported are 33-10°C. Relative humidity is of the order of 77%. Rainfall averages 1209 mm with 55 rainy days. The lake is calm over 253 days in a year.

The wave is within two meters for 250 days, storm waves upto 6.2 meters have been recorded. Annually there are severe storms for 29 days and moderate storm for 48 days; 143 days experience depression. The littoral drift has been measured at 1 to 1.3 million tonnes per year, 85% of which is within 4 meters depth and along a strip having the width of 90 to 180 meters. The drift is noticed equal to swell height when it exceeds 2 meters.

Geographical Area

The Chilka lagoon is situated on Orissa coast with maximum length of 64.5 kms. along NE-SW, maximum breadth of 18.5 kms in the northern part. It is separated from the Bay of Bengal by a barrier spit and is connected through an intricate 25 kms. long outer channel.

Because of constant siltation and tidal action, the area of Chilka is decreasing continuously. Annandale and Kemp (1915) reported the area to be 350 sq. miles (896 sq. kms.) during summer season. Fisheries Department of Government of Orissa report maximum area to be 1165 sq. kms. with minimum of 905 sq. kms. (Historical data). But as per 1986 Landsat TM data, the area is 790 sq. kms. which includes channel area of 42 sq. kms. This indicates that there is an average decrease in area of 1.45 sq. kms. per annum since 1925.

Hydrography

Scientific study of Chilka lagoon is in record since beginning of this century. Main aim of such study was to understand fish distribution pattern and effect of variation in physico-chemical conditions of the lagoon over abundance of commercial species. Annandale and Kemp (1915) recorded the distribution of salinity and its cycle in the lagoon. They also studied continuous selective influence of salinity on fauna of the lagoon. Sewell & Annandale (1922) studied changes in density of the water in Rambha zone. Besides Mitra (1946), Jhingran and Natarajan (1969) and many others have contributed a lot for study of physico-chemical and economic aspects of the lagoon.

Estuarine Biological Station, Zoological Survey of India conducted four expeditions covering all seasons during 1985-87, to study qualitative and quantitative aspects of faunal distribution in relation to Hydrography. Since September 1987 ORSAC is conducting hydrographic survey to study bathymetry, salinity, temperature, transparency, total alkalinity, dissolved oxygen, free CO₂ and nutrient content etc. (ORSAC 1988). Monthly data are being collected from 21 stations in the lagoon to study seasonal variations. An environmental data acquisition station has been established for automatic recording of 11 such parameters and tidal level variation in Chilka.

Bathymetry

Bathymetric data indicates (Fig-3) that the lagoon itself is an exceedingly shallow water body with maximum depth of 3 mts. during September, 1987. Northern part exhibits maximum depth of 1.5 mts., major portion remaining at a depth of less than 1.0 mt. In the southern part i. e. south of Balugaon, the depth increases from 2.5 mts to 3 mts. Depth of outer channel area is 1 mt. on average. During monsoon, the depth may rise by 2 mts.

Salinity

Salinity, both surface and bottom, varies (Fig. 2) considerably within the lagoon. The northern part is constantly fed by Daya-Bhargavi-Nuna rivers. So the salinity in the surroundings varies from 0 to 5 PPT. The southern part is least affected by flowing water. So salinity in this region varies from 14 to 15 PPT. The channel region indicates salinity of 7 to 32 PPT.

Temperature

Variations in the temperature of water is negligible. As per the observations surface temperature varies from 28° to 34°C where bottom temperature varies from 29° to 35°. Temperature increases in shallow water and also it is found that with increase of temperature, salinity increases.

Transparency

Considering visibility of Sacchi Disc i. e. full Sacchi Disc level, transparency of Chilka water has been calculated. It is noted, that water in southern Chilka is more transparent than rest of the area. It varies from 1.41 to 5.3. The northern zone is entirely turbid because of concentration of sediments. The central region indicates transparency of 1.88 to 8.5 whereas in the outer channel it is 1.05. (Fig 4)

It is seen that Rambha zone is more transparent than other parts of the lagoon, because of its semienclosed condition and less overland flow. During monsoon, transparency of Chilka water reduces considerably because of inflow of silt laden water. Barkudi-Bhusandpur zone is turbid throughout the year because of constant flow of silt-loaded water through Daya-Bhargavi rivers.

Dissolved oxygen

The lagoon water is usually well oxygenated throughout the year. The difference in the mean oxygen values at different zones is not remarkable. From the study undertaken by ORSAC, it is observed that the dissolved oxygen content varies from 3.3 mg/l to 11.2

mg/l. Relatively higher oxygen values (7.6-11.2 mg/l) has been recorded from Baradihi-Magarmukh zone. Surface-bottom difference is appreciable in the Rambha zone because of improper mixing.

pH

It is seen that pH of lagoon water ranges between 6.8 to 9.6. The pH values increase from channel and central region to north and south. Maximum pH of 9.6 was recorded at Rambha zone whereas the minimum pH of 6.8 was found in outer channel zone. Variation of pH may be attributed to influence of fresh water and marine water intrusion.

Total alkalinity

It is found that total alkalinity of Chilka water varies from 55 mg/l to 125 mg/l as against 20 mg/l to 260 mg/l. Higher alkalinity of 85-115 mg/l is found in Rambha zone. It is established that variation in total alkalinity follows the trend of salinity change in the lagoon water.

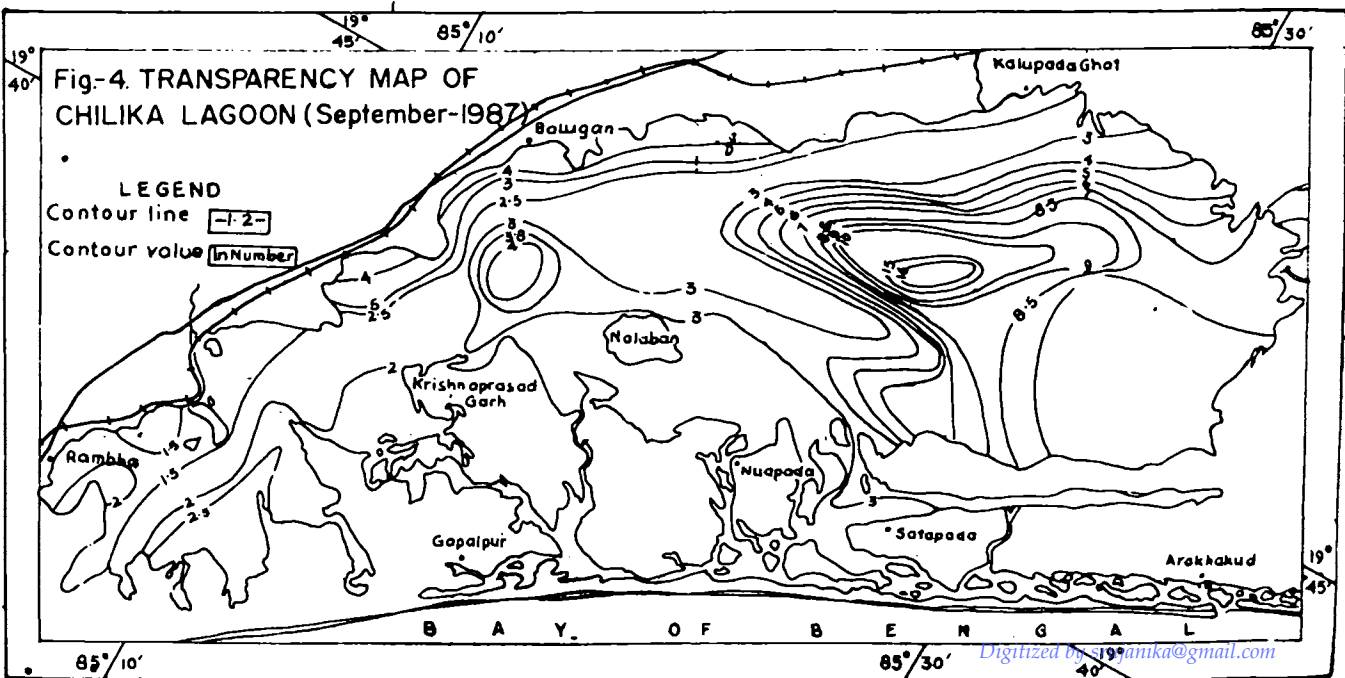
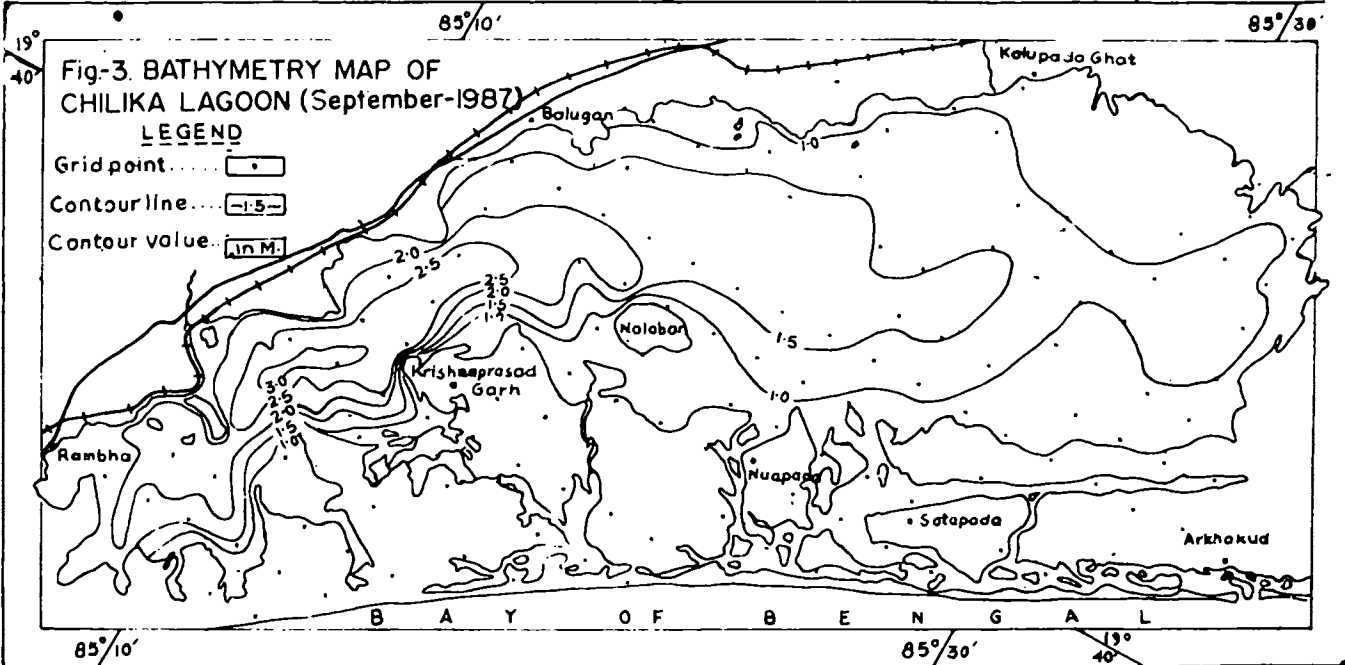
Free Carbondioxide

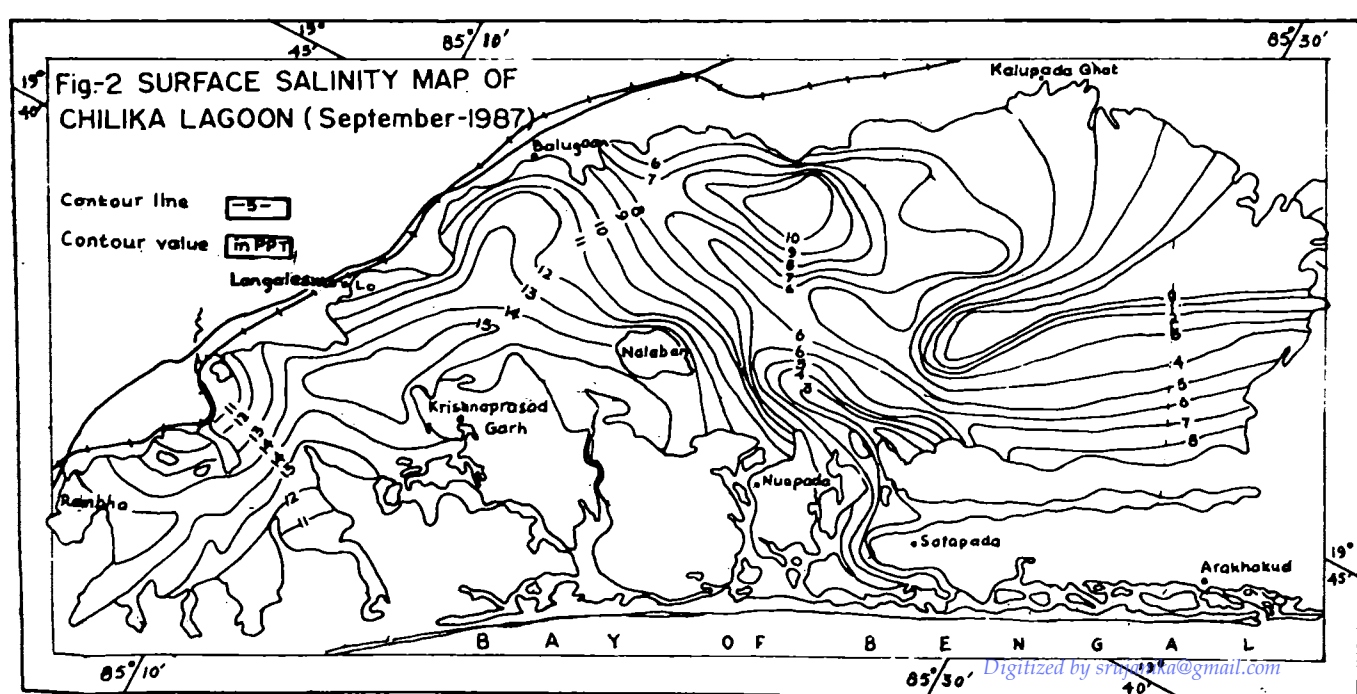
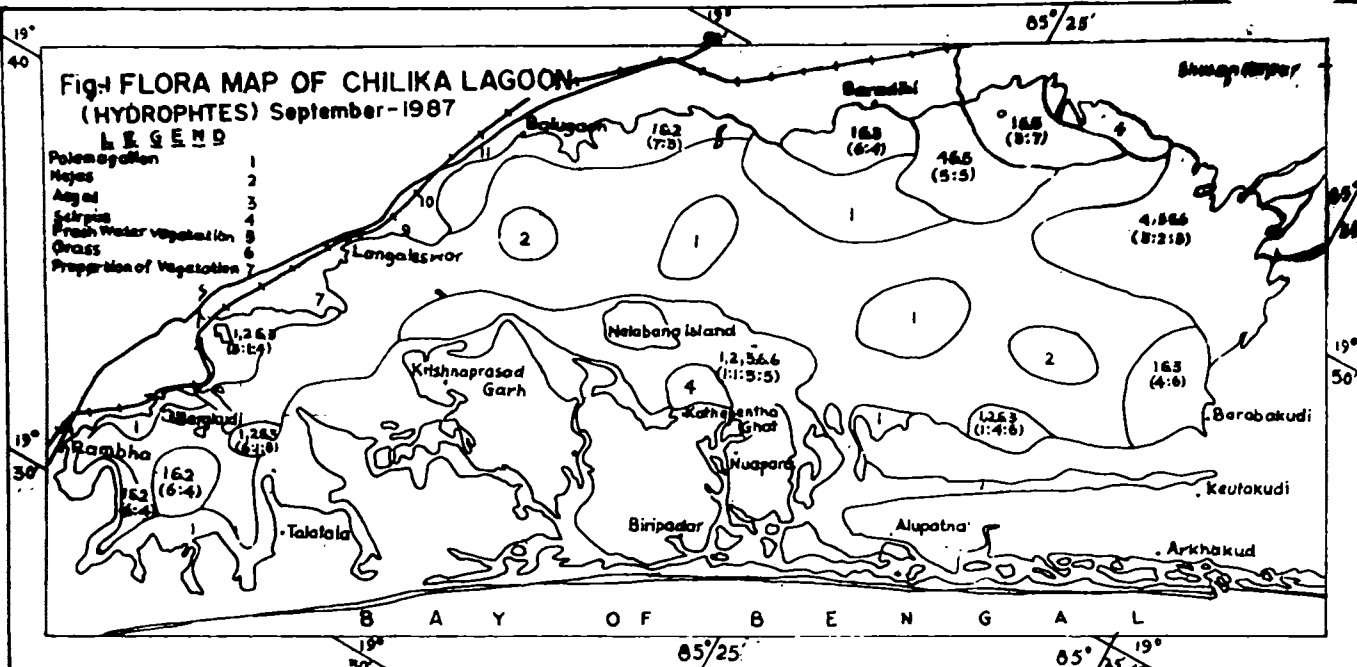
Maximum free CO₂ content of 2 mg/l is found in Baradihi-Magarmukh zone and outer channel zone. In other parts of the lagoon it is found in traces.

Flora

Macrovegetation which play important role in lagoon ecosystem, are very few in number and species (Fig-I). They can be broadly divided into two categories i.e. temporary and permanent. Temporary category includes *Eichhornia crassipes*, *Pistia stratiotes*, *Azola pinnate* etc. They are transported to Chilka through Daya-Bhargavi rivers during flooding season and remain upto March.

The permanent vegetation includes five species such as *Potamogeton pectinatus*, *Najas aveolate*, *Halophila ovata beccarii* and *Rupia maritima*. Of these, first three species are widely distributed and are of quantitative importance. Besides these 2 categories, some other marginal plants and grasses are seen. It is quite significant that floral population varies seasonally and grows gradually. (Sudarsan and Rao, 1986). During 1973, a small patch of 20 sq. kms. vegetation cover was found in NW corner. In 1977 wide dispersal was indicated which was done by continuous colonisation, covering 60 sq. kms of area. In 1982, approximately 100 sq. km. of weed zone was detected. But in 1985 it increased upto 200 sq. km. During 1988 it is estimated that total vegetation cover in Chilka lagoon is 440 sq. km. These statistics have been established by study of Landsat imageries of different seasons which indicates alarming growth of vegetation in the lagoon.





Division of Chilka

Considering the above hydrographic parameters and further correlating the data with Satellite borne data, the lagoon can be divided into atleast six major zones, i.e. (1) Barkudi-Bhusandapur zone, (2) Baradihi-Magarmukh zone, (3) Balugaon-Nalabana-Kathapenthaghat zone, (4) Balugaon-Kalijai zone, (5) Rambha zone and (6) Outer channel zone.

1) Barkudi-Bhusandpur zone : This zone is around Daya-Bhargavi-Nuna river mouth covering 128.1 sq. kms. area where fresh water drains into the lagoon. Depth of water in this zone is within 1.1 mts. Salinity is almost zero. Fresh water vegetation and fauna are seen within this area.

2) Baradihi-Magarmukh zone : This zone also contains freshwater like the former one but turbidity is less and transparency increases gradually southeastwards. Depth is more than 1.5 mts in the central part and profuse fresh water vegetation, both emerging and floating types, grow in this region. Total area covered under this zone is 200.16 sq.kms.

3) Balugaon-Nalabana-Kathapenthaghat zone : This zone, covering an area of 137.52 sq. kms, represents transitional characters of brackish water and freshwater zone. Depth is upto 2 mts and salinity varies from 8 PPT to 11 PPT. Potamogeton and Najas are prominently seen within this zone

4) Balugaon-Kalijai zone : This zone actually represents deeper portion of the lagoon with maximum depth of 3 mts. Free swimming fauna are plentifully available and active fish catching is seen within this area. Salinity is recorded upto 15 PPT. Potamogeton and Najas along with algae bodies are seen here. Area covered in this zone is 131.22 sq. kms.

5) Rambha zone : This zone is almost free from fresh water influence. The water mass is nearly equal to sea water, with maximum salinity of 15 PPT. Depth of water is above 3 meters. The zone experiences a calm environment. Brackish water flora like potamogeton and Najas are abundantly seen. The total area of this zone is 151 sq. kms.

(6) Outer channel zone : This is the most peculiar zone which is represented by a narrow intricate channel of 25 kms. long with an area of 42 sq. kms. This enables connection of Chilka to the Bay of Bengal indirectly. The channel is separated from the sea by a barrier spit on one side and the other from Chilka by a series of comparatively broad peninsulas. The channel is bifurcated with one breach being merged into marshy land. Salinity of water in this channel zone is around 7 to 32 PPT because of continuous passage of fresh water to the sea.

Shifting of Channel and Mouth

It is studied from landsat TM imagery that there have been 3 shifts of the channel, The earlier location being near Taltala, Krishnaprasadgarh and Tichhini. Presence of

Jahnikuda-Nuapara and Barunkuda islands also trifurcate the present configuration of the channel. It is reported that the opening mouth of the channel was near Arkhakuda, during 1914 (Annandale and Kemp, 1915). Now this has been shifted by 6 kms NE of the said point.

Landuse/Landcover Mapping of Chilka Catchment Area.

Landuse/landcover map of Chilka watershed was prepared by interpretation of Landsat TM FCC on scale 1 : 50,000 and followed by subsequent ground truthing. Ground truthing data and historical data were collected for collation of the map. After careful analysis of the above sets of data, the following classes have been identified, in the total area of 4,300 sq. kms.

- | | |
|---------------------|--|
| 1. Built-up land | Settlement, roads, highways, railways, earthen embankment. |
| 2. Agriculture land | Under regular cultivation lowlying area cultivation. |
| 3. Waterbodies | Ponds, reservoirs, streams, other waterbodies. |
| 4. Forest land | Degraded forest, dense forest, plantation and degraded plantation. |
| 5. Wetland-Marshes | Wet & muddy, mud with grass dry and muddy. |
| Swamps | |
| Grassy land | |
| 6. Coastal islands | Under water, sandy island. |
| 7. Aquaculture | Prawn culture ponds. |
| 8. Wasteland-Sands | Beach sand, beach ridges scrubby sands. |
| | Gullied land, undulating upland, barren rocks. |

Recommendation and Conclusion

Basing on the observations made by ORSAC and other scientists, it can be concluded that Chilka lagoon experiences a highly dynamic brackish water environment with appreciable seasonal variations in hydrographic parameters, vegetation, sedimentation and other topographic features. For conservation of lagoonal characteristics, the following studies are recommended.

- i) Hydrographic and salinity model study.
- ii) Tidal fluctuation and tidal prism study.

Besides above the following measures may be undertaken for protection of Chilka lagoon.

- i) Conservation measures in priority area of 4600 hect. in Chilka periphery may be taken up to prevent soil erosion.
- ii) Aquaculture may be practised over 20 sq. kms. of area in between Chilka and Bay of Bengal, west and north-west of Chilka.
- iii) A green belt of 200 mts. wide may be developed around Chilka periphery of 200 kms to prevent over land flow and soil erosion.
- iv) Over fishing should be prohibited and outer channel zone may be declared as "no fishing zone".
- v) 3 kms. of area around Nalabana may be declared as prohibited area.
- vi) Peripheral area, specifically 73 sq. kms. of area NW of Chilka may be excavated to increase waterspread of Chilka. The peripheral shallow water zone may be excavated upto a minimum depth of 1 mt. Due care may be taken to increase gradually water spread of Chilka to 900 sq. kms.
- vii) The outer channel zone may be cleared by excavating unwanted islands and shoals for free movement of silt water to prevent siltation in Chilka.
- viii) Measures may be taken up for stabilisation of mouth of the lagoon.
- ix) A new cut may be excavated across the spit to reduce the 25 kms. long connecting channel to 8.5 kms. This will enhance easy fluxing of marine water in Chilka and increase in salinity level.
- x) Weeds may be removed by mechanical harvesters and culturing carps.

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Bibliography on Chilika Lagoon

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About 200 references on the fauna, flora, fisheries, hydrography, ecology, conservation and development of the Chilika lagoon are listed as a guide to the widely scattered literature on the Chilika lagoon studies.

Introduction

The first faunistic study on Chilika lagoon located along the east coast of India between latitudes 19°28' and 19°54' N and longitudes 85°06' and 85°35' E was initiated by the Zoological Survey of India as early as 1914. Results of these studies have been published in a series of papers from 1915 to 1924 in the volume V of *Memoirs of the Indian Museum*. Detailed fishery investigations were undertaken since 1956 by the Central Inland Fisheries Research Institute. The State Fisheries station, Balugaon has been carrying out biological and technological studies in relation to the fisheries of the Chilika lagoon since 1948. The Estuarine Biological Station of the Zoological Survey of India has taken up the resurvey of the Chilika lagoon through a multi-disciplinary team drawn from various research and academic institutions. The results are expected by the end of 1990.

Owing to the growing awareness to protect and conserve the Chilika lagoon, the largest brackish water body of India, it is now felt necessary to monitor the lagoon for its integrated development from fisheries to tourism. Before proposing any developmental project on Chilika lagoon, as it plays an important role in the economy of Orissa state, one should be aware of earlier information for submitting realistic and feasible action plans. To achieve the above objects the authors made an attempt to list out the available literature on Chilika lagoon.

The references have been listed out alphabetically and most of the cited references herein have been checked with original works. The authors made efforts to include as many references as possible in the present work and the missing ones will be published as a supplement to the present bibliography on Chilika lagoon.

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